

OGC GeoSPARQL - A Geographic Query Language for RDF Data

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Simon J.D. Cox

OGC GeoSPARQL - A Geographic Query Language for RDF Data

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i. Preface

The GeoSPARQL standard defines:

- a formal *profile*
- **this specification document**
 - a core RDF/OWL ontology for geographic information representation
- a set of SPARQL extension functions
- a Functions & Rules vocabulary, derived from the ontology
- a Simple Features feature types vocabulary
- a set of RIF rules, and
- SHACL shapes for RDF data validation

This document has the role of *specification* and authoritatively defines many of the standard's elements, including the ontology classes and properties, SPARQL functions and function and rule vocabulary concepts. Complete descriptions of the standard's parts and their roles are given in the Introduction in the section [GeoSPARQL Standard structure](#).

ii. Submitting organizations

The following organizations submitted this Implementation Specification to the Open Geospatial Consortium Inc.:

- a. Australian Bureau of Meteorology
- b. Bentley Systems, Inc.
- c. CSIRO
- d. Defence Geospatial Information Working Group (DGIWG)
- e. GeoConnections - Natural Resources Canada
- f. Interactive Instruments GmbH
- g. GeoScape Australia
- h. Mainz University Of Applied Sciences
- i. Oracle America
- j. Ordnance Survey
- k. Raytheon Company
- l. SURROUND Australia Pty Ltd.
- m. Traverse Technologies, Inc.
- n. US Geological Survey (USGS)

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| Timo Homburg | Mainz University Of Applied Sciences |
| Joseph Abhayaratna | GeoScape Australia |
| Simon J.D. Cox | CSIRO |

iv. Revision history

| Date | Release | Author | Paragraph modified | Description |
|---------------|-----------|--------------------|-----------------------|--|
| 27 Oct. 2009 | Draft | Matthew Perry | Clause 6 | Technical Draft |
| 11 Nov. 2009 | Draft | John R. Herring | All | Creation |
| 06 Jan. 2010 | Draft | John R. Herring | All | Comment responses |
| 30 March 2010 | Draft | Matthew Perry | All | Comment responses |
| 26 Oct. 2010 | Draft | Matthew Perry | All | Revision based on working group discussion |
| 28 Jan. 2011 | Draft | Matthew Perry | All | Revision based on working group discussion |
| 18 April 2011 | Draft | Matthew Perry | All | Restructure with multiple conformance classes |
| 02 May 2011 | Draft | Matthew Perry | Clause 6 and Clause 8 | Move Geometry Class from core to geometryExtension |
| 05 May 2011 | Draft | Matthew Perry | All | Update URIs |
| 13 Jan. 2012 | Draft | Matthew Perry | All | Revision based on Public RFC |
| 16 April 2012 | Draft | Matthew Perry | All | Revision based on adoption vote comments |
| 19 July 2012 | 1.0 | Matthew Perry | All | Revision of URIs based on OGC Naming Authority recommendations |
| 09 Oct. 2020 | 1.1 Draft | Joseph Abhayaratna | All | Establishment of the 1.1 Specification |

| Date | Release | Author | Paragraph modified | Description |
|------------------------|-----------|-------------------|--------------------|------------------------------------|
| 10 Oct. 2020 | 1.1 Draft | GeoSPARQL 1.1 SWG | All | Addition of GeoSPARQL 1.1 elements |
| to 15 Aug. 2021 | | | | |

Major changes between versions 1.0 and 1.1

Version 1.1 of GeoSPARQL was released approximately 9 years after version 1.0. It contains no breaking changes to 1.0, but does contain additions: whole new profile resources, new ontology elements and new functions. The major changes are given in the tables below.

These new profile resources are resources - documents - that are separate from this specification. The new *profile definition* lists all the GeoSPARQL 1.1 resources.

| New resource | Location |
|------------------------|---|
| Profile definition | http://www.opengis.net/def/geosparql |
| GeoSPARQL Rules in RIF | http://www.opengis.net/def/geosparql-rifrules |
| RDF validation file | http://www.opengis.net/def/geosparql-shapes |

These new ontology elements and new functions are normatively defined in this specification document.

| New element | Section |
|----------------------------------|-------------------------------|
| <i>Classes</i> | |
| Spatial Object Collection class | Section 6.2.3 |
| Feature Collection class | Section 6.2.4 |
| Geometry Collection class | Section 8.2.2 |
| <i>Spatial Object Properties</i> | |
| hasSize | Section 6.3.1 |
| hasMetricSize | Section 6.3.2 |
| hasLength | Section 6.3.3 |
| hasMetricLength | Section 6.3.4 |
| hasPerimeterLength | Section 6.3.5 |
| hasMetricPerimeterLength | Section 6.3.6 |
| hasArea | Section 6.3.7 |
| hasMetricArea | Section 6.3.8 |
| hasVolume | Section 6.3.9 |

| New element | Section |
|--|---------------------------------|
| hasMetricVolume | Section 6.3.10 |
| <i>Feature Properties</i> | |
| hasBoundingBox | Section 6.4.3 |
| hasCentroid | Section 6.4.4 |
| <i>Geometry Serializations</i> | |
| geoJSONLiteral | Section 8.4.3.1 |
| asGeoJSON | Section 8.4.3.2 |
| asGeoJSON function | Section 8.4.3.3 |
| kmlLiteral | Section 8.4.4.1 |
| asKML | Section 8.4.4.2 |
| asKML function | Section 8.4.4.3 |
| dggsLiteral | Section 8.4.5.1 |
| asDGGS | Section 8.4.5.2 |
| asDGGS function | Section 8.4.5.3 |
| <i>Non-topological Query Functions</i> | |
| maxX | Section 8.5.18 |
| maxY | Section 8.5.19 |
| maxZ | Section 8.5.20 |
| minX | Section 8.5.21 |
| minY | Section 8.5.22 |
| minZ | Section 8.5.23 |
| <i>Spatial Aggregate Functions</i> | |
| aggBoundingBox | Section 8.6.1 |
| aggBoundingCircle | Section 8.6.2 |
| aggCentroid | Section 8.6.3 |
| aggConcatLines | Section 8.6.4 |
| aggConcaveHull | Section 8.6.5 |
| aggUnion | Section 8.6.7 |

v. Changes to the OGC® Abstract Specification

The OGC® Abstract Specification does not require changes to accommodate this OGC® standard.

Foreword

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights. However, to date, no such rights have been claimed or identified.

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the specification set forth in this document, and to provide supporting documentation.

Introduction

The W3C Semantic Web Activity is defining a collection of technologies that enables a “web of data” where information is easily shared and reused across applications. Some key pieces of this technology stack are the RDF (Resource Description Framework) data model [\[RDF\]](#), [\[RDFS\]](#), the OWL Web Ontology Language [\[OWL2\]](#) and the SPARQL protocol and RDF query language [\[SPARQL\]](#).

RDF

RDF is, among other things, a data model built on edge-node “graphs.” Each link in a graph consists of three things (with many aliases depending on the mapping from other types of data models):

- Subject (start node, instance, entity, feature)
- Predicate (verb, property, attribute, relation, member, link, reference)
- Object (value, end node, non-literal values can be used as a Subject)

Any of the three values in a triple can be represented with a Internationalized Resource Identifier (IRI) [\[IETF3987\]](#), which globally and uniquely identifies the resource referenced. IRIs are an extension to Universal Resource Identifiers (URIs) that allow for non-ASCII characters. In addition to functioning as identifiers, IRIs are usually, but not necessarily, resolvable which means a person or machine can “dereference” them (*click on them* or otherwise action them) and be taken to more information about the resource, perhaps in a web browser.

Subjects and objects within an RDF triple are called nodes and can also be represented with a blank node (a local identifier with meaning outside the graph it is defined within). Objects can further be represented with a literal value. Basic literal values in RDF are those used in XML [\[XSD2\]](#) but the basic types can be extended for specialised purposes and in this specification are, for geometry data. The figure below shows a basic triple.

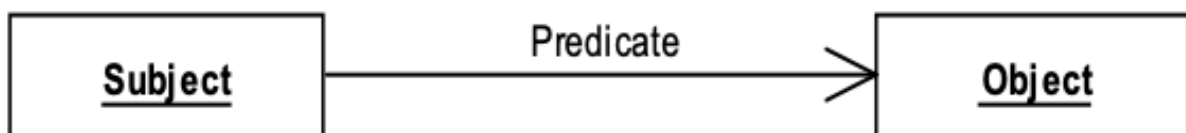


Figure 1. An RDF Triple

Note that the same node may be a subject in some triples, and an object in others.

Almost all data can be presented or represented in RDF. In particular, it is an easy match to the (feature-instance-by-id, attribute, value) tuples of the General Feature Model [\[ISO19109\]](#), and for the relational model as (table primary key, column, value).

SPARQL

From [\[SPARQL\]](#):

SPARQL ... is a set of specifications that provide languages and protocols to query and manipulate RDF graph content on the Web or in an RDF store.

and, from Wikipedia^[1]:

SPARQL (pronounced "sparkle" /ˈspɑːrkəl/, a recursive acronym for SPARQL Protocol and RDF Query Language) is an RDF query language - that is, a semantic query language for databases — able to retrieve and manipulate data stored in Resource Description Framework (RDF) format. It was made a standard by the RDF Data Access Working Group (DAWG) of the World Wide Web Consortium, and is recognized as one of the key technologies of the semantic web. On 15 January 2008, SPARQL 1.0 was acknowledged by W3C as an official recommendation, and SPARQL 1.1 in March, 2013.

SPARQL queries work on RDF representations of data by finding patterns that match templates in the query, in effect finding information graphs in the RDF data based on the templates and filters (constraints on nodes and edges) expressed in the query. This query template is represented in the SPARQL query by a set of parameterized “query variables” appearing in a sequence of RDF triples and filters. If the query processor finds a set of triples in the data (converted to an RDF graph in some predetermined standard manner) then the values that the “query variables” take on in those triples become a solution to the query request. The values of the variables are returned in the query result in a format based on the “SELECT” clause of the query (similar to SQL).

In addition to predicates defined in this manner, the SPARQL query may contain filter functions that can be used to further constrain the query. Several mechanisms are available to extend filter functions to allow for predicates calculated directly on data values. The SPARQL specification [SPARQL] in section 17.6^[2] describes the mechanism for invocation of such a filter function.

The OGC GeoSPARQL standard supports representing and querying geospatial data on the Semantic Web. GeoSPARQL defines a vocabulary for representing geospatial data in RDF, and it defines extensions to the SPARQL query language for processing geospatial data.

GeoSPARQL Standard structure

The GeoSPARQL standard comprises multiple parts:

- a formal *profile*
 - <http://www.opengis.net/def/geosparql>
 - defined according to the *Profiles Vocabulary* [PROF]
 - this relates the parts in the standard together, provides access to them, and declares dependencies on other standards
- **this specification document**
 - which defines many of the standard’s parts
- a core RDF/OWL [RDF],[OWL2] ontology for geographic information representation
 - based on the General Feature Model [ISO19109], Simple Features [ISO19125-1], Feature Geometry [ISO19107] and SQL MM [ISO13249]

- defined within the specification document and delivered in RDF also
- a Functions & Rules vocabulary, derived from the ontology
 - presented as a [\[SKOS\]](#) taxonomy
- a Simple Features feature types vocabulary
 - presented as a [\[SKOS\]](#) taxonomy
- a set of SPARQL [\[SPARQL\]](#) extension functions
 - defined within the specification document
- a set of RIF [\[RIFCORE\]](#) rules, and
 - templated within the specification document
 - also delivered as a RIF document also
- SHACL [\[SHACL\]](#) shapes for RDF data validation
 - defined within a shapes graph file

This specification document follows further modular design; it comprises several different components:

- a *core* component defining the top-level RDFS/OWL classes for spatial objects
- a *topology vocabulary* component defining the RDF properties for asserting and querying topological relations between spatial objects
- a *geometry* component defines RDFS data types for serializing geometry data, geometry-related RDF properties, and non-topological spatial query functions for geometry objects
- a *geometry topology* component defining topological query functions
- an *RDFS entailment* component defining mechanisms for matching implicit RDF triples that are derived based on RDF and RDFS semantics
- a *query rewrite* component defining rules for transforming a simple triple pattern that tests a topological relation between two features into an equivalent query involving concrete geometries and topological query functions

Each of these specification components forms a *requirements class* (a set of requirements) for GeoSPARQL. Implementations can provide various levels of functionality by choosing which requirements classes to support. For example, a system based purely on qualitative spatial reasoning may support only the core and topological vocabulary components.

In addition, GeoSPARQL is designed to accommodate systems based on qualitative spatial reasoning and systems based on quantitative spatial computations. Systems based on qualitative spatial reasoning, (e.g. those based on the Region Connection Calculus [\[QUAL\]](#), [\[LOGIC\]](#)) do not usually model explicit geometries, so queries in such systems will likely test for binary spatial relationships between features rather than between explicit geometries. To allow queries for spatial relations between features in quantitative systems, GeoSPARQL defines a series of query transformation rules that expand a feature-only query into a geometry-based query. With these transformation rules, queries about spatial relations between features will have the same specification in both qualitative systems and quantitative systems. The qualitative system will likely evaluate the query

with a backward-chaining spatial “reasoner”, and the quantitative system can transform the query into a geometry-based query that can be evaluated with computational geometry.

[1] <https://en.wikipedia.org/wiki/SPARQL>

[2] <https://www.w3.org/TR/sparql11-query/#extensionFunctions>

OGC GeoSPARQL – A Geographic Query Language for RDF Data

1. Scope

This is the specification document for GeoSPARQL which, as a whole, comprises multiple parts. See the Introduction section [GeoSPARQL Standard structure](#) for details of the parts.

GeoSPARQL does not define a comprehensive vocabulary for representing spatial information. It instead defines a core set of classes, properties and datatypes that can be used to construct query patterns. Many useful extensions to this vocabulary are possible, and we intend for the Semantic Web and Geographic Information System (GIS) communities to develop additional vocabulary for describing spatial information.

2. Conformance

Conformance with this specification shall be checked using all the relevant tests specified in *Annex A — Abstract Test Suite*. The framework, concepts, and methodology for testing, and the criteria to be achieved to claim conformance are specified in *ISO 19105: Geographic information — Conformance and Testing* [ISO19105].

This document establishes several requirements classes and corresponding conformance classes (a conformance class is a set of tests for each requirement in a requirements class). Any GeoSPARQL implementation claiming conformance with one of the conformance classes shall pass all the tests in the associated abstract test suite.

Requirements and conformance tests have IRIs that are relative to versioned namespace IRIs. Requirements and conformance test that are defined in GeoSPARQL 1.0 have IRIs relative to <http://www.opengis.net/spec/geosparql/1.0/>, requirements and conformance test that are added in GeoSPARQL 1.1 have IRIs relative to <http://www.opengis.net/spec/geosparql/1.1/>.

Many conformance classes are parameterized. For parameterized conformance classes, the list of parameters is given within parenthesis.

Table 1. Conformance Classes

| Conformance class | Description | Subclause of the abstract test suite |
|--|---|--------------------------------------|
| Core | Defines top-level spatial vocabulary components | A.1 |
| Topology Vocabulary Extension (relation_family) | Defines topological relation vocabulary | A.2 |
| Geometry Extension (serialization, version) | Defines geometry vocabulary and non- topological query functions | A.3 |
| Geometry Topology Extension (serialization, version, relation_family) | Defines topological query functions for geometry objects | A.4 |
| RDFS Entailment Extension (serialization, version , relation_family) | Defines a mechanism for matching implicit RDF triples that are derived based on RDF and RDFS semantics | A.5 |
| Query Rewrite Extension (serialization, version, relation_family) | Defines query transformation rules for computing spatial relations between spatial objects based on their associated geometries | A.6 |

Dependencies between each GeoSPARQL requirements class are shown below in Figure 2. To support a requirements class for a given set of parameter values, an implementation must support each dependent requirements class with the same set of parameter values.

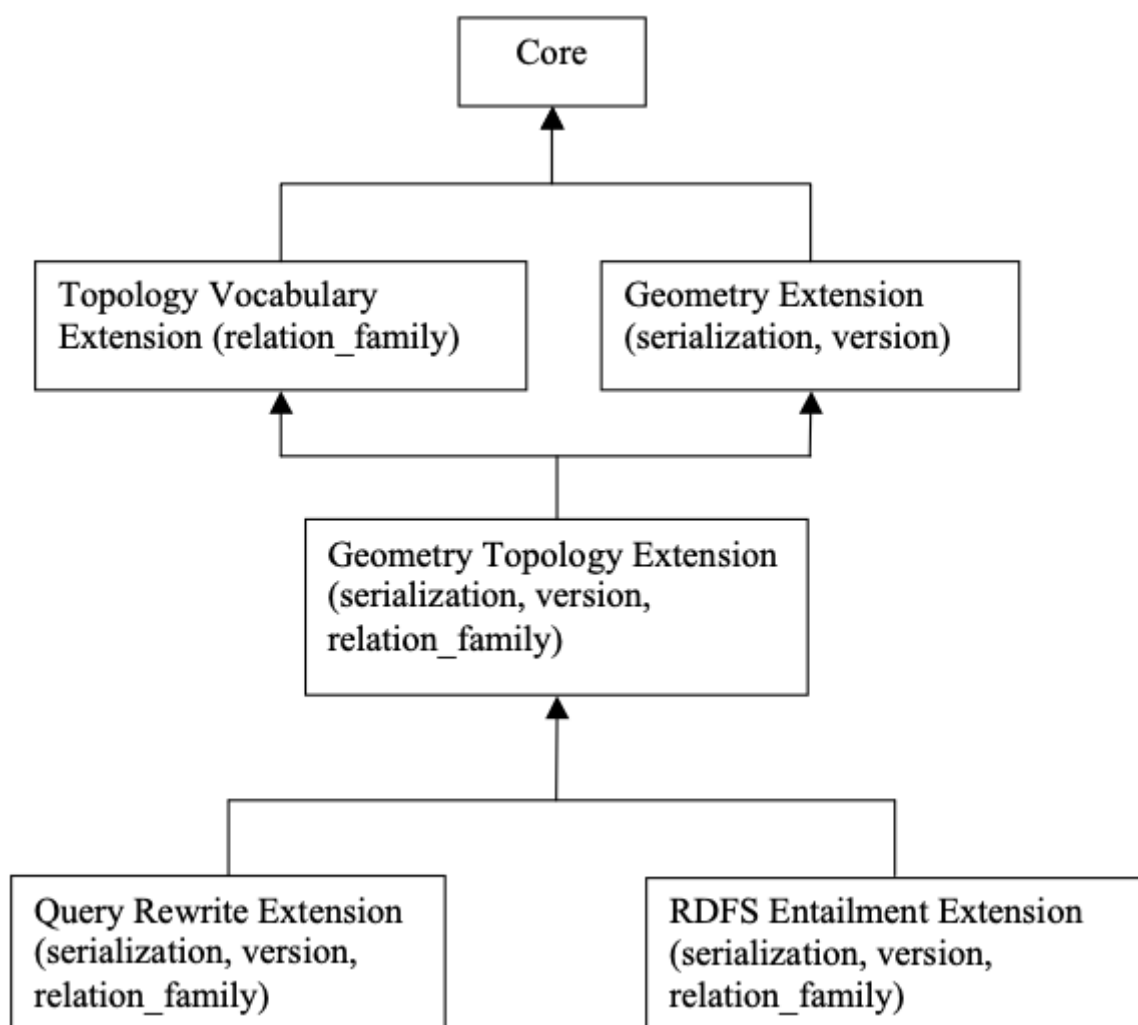


Figure 2. Requirements Class Dependency Graph

3. Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

Items in this list are linked to their full citation [Bibliography](#).

- [\[ISO19125-1\]](#), *ISO 19125-1: Geographic information — Simple feature access — Part 1: Common architecture*
- [\[ISO19156\]](#), *ISO 19156: Geographic information — Observations and measurements*
- [\[OGC07-036\]](#), *OGC 07-036: Geography Markup Language (GML) Encoding Standard*
- [\[IETF3987\]](#), Internet Engineering Task Force, *RFC 3987: Internationalized Resource Identifiers (IRIs)*
- [\[OWL2\]](#) *OWL 2 Web Ontology Language Document Overview (Second Edition)*
- [\[RDF\]](#), *RDF 1.1 Concepts and Abstract Syntax*
- [\[RDFS\]](#) *RDF Schema 1.1*
- [\[RIFCORE\]](#), *RIF Core Dialect (Second Edition)*
- [\[SPARQL\]](#), *SPARQL 1.1 Query Language*
- [\[SPARQLENT\]](#), *SPARQL 1.1 Entailment Regimes*
- [\[SPARQLPROT\]](#), *SPARQL 1.1 Protocol*
- [\[SPARQLRESX\]](#), *SPARQL Query Results XML Format (Second Edition)*
- [\[SPARQLRESJ\]](#), *SPARQL 1.1 Query Results JSON Format*

4. Terms and definitions

For the purposes of this document, the terms and definitions given in the above normative references apply, as well as those reproduced or created in this section.

4.1. Semantic Web

The following terms and their definitions relate to Semantic Web models, tools and methods.

4.1.1. RDF

The Resource Description Framework (RDF) is a framework for representing information in the Web. RDF graphs are sets of subject-predicate-object triples, where the elements may be IRIs, blank nodes, or datatyped literals. They are used to express descriptions of resources. [\[RDF\]](#)

4.1.2. RDFS

RDF Schema provides a data-modelling vocabulary for RDF data. RDF Schema is an extension of the basic RDF vocabulary. [\[RDFS\]](#)

4.1.3. OWL

The OWL 2 Web Ontology Language, informally OWL 2, is an ontology language for the Semantic Web with formally defined meaning. OWL 2 ontologies provide classes, properties, individuals, and data values and are stored as Semantic Web documents. OWL 2 ontologies can be used along with information written in RDF, and OWL 2 ontologies themselves are primarily exchanged as RDF documents. [\[OWL2\]](#)

4.1.4. SPARQL

SPARQL is a query language for RDF. The results of SPARQL queries can be result sets or RDF graphs. [\[SPARQL\]](#)

4.2. Spatial

The following terms and their definitions relate to spatial science and data.

4.3. coordinate system

A coordinate system is a set of mathematical rules for specifying how coordinates are to be assigned to points.

4.4. coordinate reference system

A coordinate reference system (CRS) is a coordinate system that is related to an object by a datum.

4.5. datum

A datum is a parameter or set of parameters that define the position of the origin, the scale, and the orientation of a coordinate system.

4.6. discrete global grid system

A discrete global grid system (DGGS) is a spatial reference system that represents the Earth, or any other globe-like object, with a tessellation of nested cells. Generally, a DGGS will exhaustively partition the globe in closely packed hierarchical tessellations, each cell representing a homogenous value, with a unique identifier or indexing that allows for linear ordering, parent-child operations, and nearest neighbour algebraic operations.

4.7. spatial reference system

A spatial reference system (SRS) is a system for establishing spatial position. A spatial reference system can use geographic identifiers (place names, for example), coordinates (in which case it is a coordinate reference system), or identifiers with structured geometry (in which case it is a discrete global grid system).

5. Conventions

5.1. Symbols and abbreviated terms

In this specification, the following common acronyms are used:

| | |
|---------|---|
| CRS | Coordinate Reference System |
| DGGs | Discrete Global Grid System |
| 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 |
| SRS | Spatial Reference System |
| 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 |

5.2. Namespaces

The following IRI namespace prefixes are used throughout this document:

| | |
|-------|---|
| ex: | http://example.com/ |
| 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# |
| my: | http://example.org/ApplicationSchema# |
| ogc: | http://www.opengis.net/ |
| 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#>
skos: <http://www.w3.org/2004/02/skos/core#>
xsd: <http://www.w3.org/2001/XMLSchema#>

5.3. Placeholder IRIs

All of these namespace prefixes in the previous section resolve to resources that contain their namespace content except for **eg:** (<http://example.com/>), which is used just for examples, and **ogc:** (<http://www.opengis.net/>), which is used in requirement specifications as a placeholder for the geometry literal serialization used in a fully-qualified conformance class, e.g. `<http://www.opengis.net/ont/geosparql#wktLiteral>`.

5.4. RDF Serializations

Three RDF serializations are used in this document. Terse RDF Triple Language (turtle) [\[TURTLE\]](#) is used for RDF snippets placed within the main body of the document, and turtle, JSON-LD [\[JSON-LD\]](#) & RDF/XML [\[RDFXML\]](#) is used for the examples in *Annex B — GeoSPARQL Examples*.

6. Core

This clause establishes the **core** requirements class, with IRI [/req/core](#), which has a single corresponding conformance class, **core**, with IRI [/conf/core](#). This requirements class defines a set of classes and properties for representing geospatial data. The resulting vocabulary - an ontology - can be used to construct SPARQL graph patterns for querying appropriately modeled geospatial data. RDFS and OWL vocabulary have both been used so that the vocabulary can be understood by systems that support only RDFS entailment and by systems that support OWL-based reasoning.

The figure below overviews the classes and properties defined by GeoSPARQL in the **core**, **Topology Vocabulary Extension** and **Geometry Extension**, **Geometry Topology Extension** and **RDFS Entailment Extension** requirements classes.

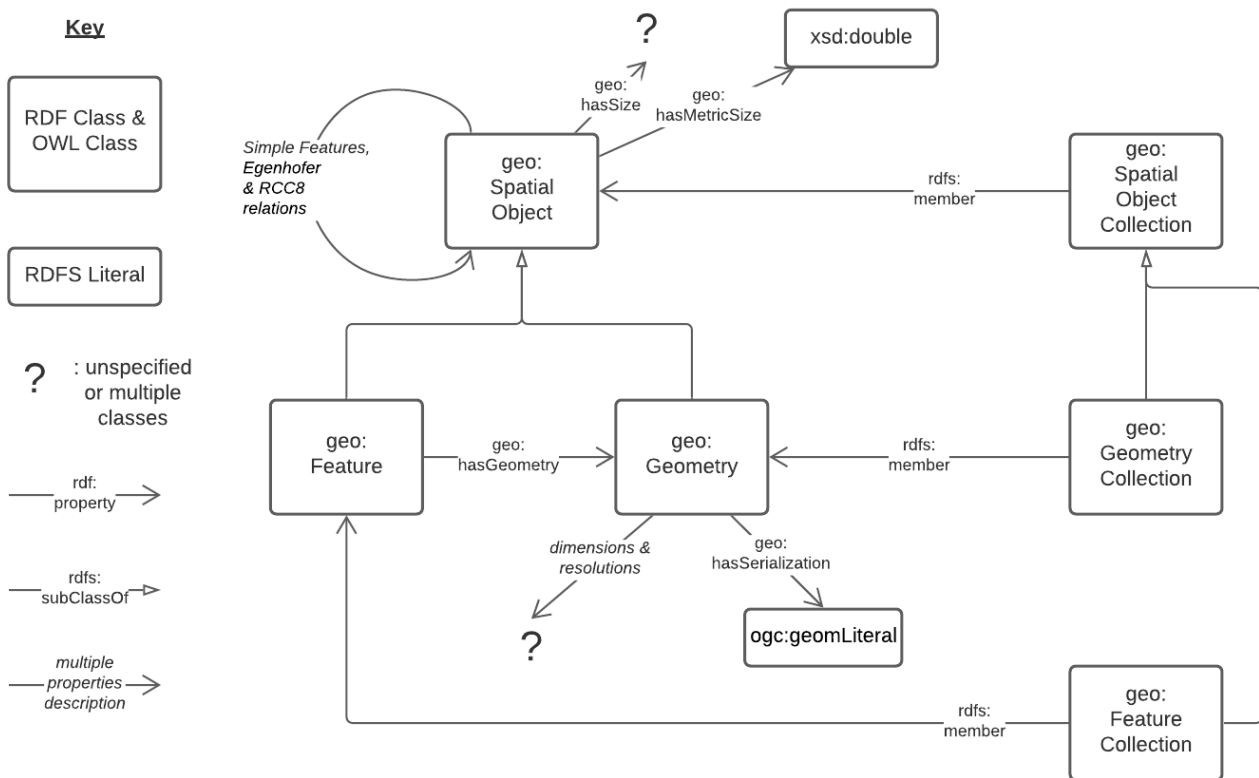


Figure 3. An overview of the Classes and Properties defined in GeoSPARQL. Where specific Classes and Properties are indicated, their prefixed forms of their ontology identifiers (IRIs) are given. Where types or collections of properties are given, they are described in *italics*. Where unspecified Classes are given, they are represented with a question mark. For cardinalities and other ontology restrictions, see the ontology document. Subproperties of **geo:hasSize**, its metric equivalent and **geo:hasSerialization** are not shown for clarity.

6.1. SPARQL

Req 1 Implementations shall support the SPARQL Query Language for RDF [\[SPARQL\]](#), the SPARQL Protocol [\[SPARQLPROT\]](#) and the SPARQL Query Results XML [\[SPARQLRESX\]](#) and JSON [\[SPARQLRESJ\]](#) Formats.

<http://www.opengis.net/spec/geosparql/1.0/req/core/sparql-protocol>

6.2. Classes

Two main classes are defined: `geo:SpatialObject` and `geo:Feature`. The class `geo:Feature` is equivalent to the UML class `Feature` defined in [ISO19109].

Two container classes are defined: `Spatial Object Collection` and `Feature Collection`.

6.2.1. Class: `geo:SpatialObject`

The class `geo:SpatialObject` is defined by the following:

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

Req 2 Implementations shall allow the RDFS class `geo:SpatialObject` to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.0/req/core/spatial-object-class>

Example:

```
eg:x
  a geo:SpatialObject ;
  skos:prefLabel "Object X";
.
```

6.2.2. Class: `geo:Feature`

The class `geo:Feature` is equivalent to the class `GFI_Feature` [ISO19156] and is defined by the following:

```
geo:Feature
  a rdfs:Class, owl:Class ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "Feature"@en ;
  rdfs:subClassOf geo:SpatialObject ;
  owl:disjointWith geo:Geometry ;
  skos:definition "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 .
```

Req 3 Implementations shall allow the RDFS class `geo:Feature` to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.0/req/core/feature-class>

6.2.3. Class: `geo:SpatialObjectCollection`

The class `geo:SpatialObjectCollection` is defined by the following:

```
geo:SpatialObjectCollection
  a owl:Class ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "Spatial Object Collection" ;
  skos:definition "The class Spatial Object Collection represents any collection of
                    individual Spatial Objects. It is superclass of Feature Collection
                    and Geometry Collection."@en ;
  rdfs:subClassOf rdfs:Container ;
  rdfs:subClassOf [
    a owl:Restriction ;
    owl:allValuesFrom geo:SpatialObject ;
    owl:onProperty rdfs:member ;
  ] ;
.
```

The restriction imposed on the generic `rdfs:Container` that defines this class is that only instances of `Spatial Object` are allowed to be members of it and these are indicated with the `rdfs:member` property.

Req 5 Implementations shall allow the RDFS class `geo:SpatialObjectCollection` to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.1/req/core/spatial-object-collection-class>

6.2.4. Class: `geo:FeatureCollection`

The class `geo:FeatureCollection` is defined by the following:


```

geo:FeatureCollection
  a owl:Class ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "Feature Collection" ;
  skos:definition "The class Feature Collection represents
                  any collection of individual Features."@en ;
  rdfs:subClassOf geo:SpatialObjectCollection ;
  rdfs:subClassOf [
    a owl:Restriction ;
    owl:allValuesFrom :Feature ;
    owl:onProperty rdfs:member ;
  ] ;
.

```

The restriction imposed on the more general [Spatial Object Collection](#) that defines this class is that only instances of [Feature](#) are allowed to be members of it and these are to be indicated with the [rdfs:member](#) property.

Req 6 Implementations shall allow the RDFS class [geo:FeatureCollection](#) to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.1/req/core/feature-collection-class>

6.3. Standard Properties for geo:SpatialObject

Properties are defined for associating Spatial Objects with scalar spatial measurements (sizes) .

Req 7 Implementations shall allow the properties [geo:hasSize](#), [geo:hasMetricSize](#), [geo:hasLength](#), [geo:hasMetricLength](#), [geo:hasPerimeterLength](#), [geo:hasMetricPerimeterLength](#), [geo:hasArea](#), [geo:hasMetricArea](#), [geo:hasVolume](#) and [geo:hasMetricVolume](#). to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.1/req/core/spatial-object-properties>

6.3.1. Property: geo:hasSize

The property [geo:hasSize](#) is the superproperty of all properties that can be used to indicate the size of a Spatial Object in case (only) metric units (meter, square meter or cubic meter) can not be used. If it is possible to express size in metric units, subproperties of [geo:hasMetricSize](#) should be used. This property has not range specification. This makes it possible to use other vocabularies for expressions of size, for example vocabularies for units of measurement or vocabularies for specifying measurement quality.

GeoSPARQL 1.1 defines the following subproperties of this property: [geo:hasLength](#), [geo:hasPerimeterLength](#), [geo:hasArea](#) and [geo:hasVolume](#).

```

geo:hasSize
  a rdf:Property, owl:ObjectProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:domain geo:SpatialObject ;
  skos:definition "Subproperties of this property are used to indicate the size of a
                  Spatial Object as a measurement or estimate of one or more
dimensions
                  of the Spatial Object's spatial presence."@en ;
  skos:prefLabel "has size"@en ;
.

```

6.3.2. Property: `geo:hasMetricSize`

The property `geo:hasMetricSize` is the superproperty of all properties that can be used to indicate the size of a Spatial Object using metric units (meter, square meter or cubic meter). Using a subproperty of this property is the recommended way to specify size, because using a standard unit of length (meter) benefits data interoperability and simplicity. Subproperties of `geo:hasSize` can be used if more complex expressions are necessary, for example if the unit of length can not be converted to meter, or if additional data are needed to describe the measurement or estimate of size.

GeoSPARQL 1.1 defines the following subproperties of this property: `geo:hasMetricLength`, `geo:hasMetricPerimeterLength`, `geo:hasMetricArea` and `geo:hasMetricVolume`.

```

geo:hasMetricSize
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:domain geo:SpatialObject ;
  rdfs:range xsd:double ;
  skos:definition "Subproperties of this property are used to indicate the size of a
                  Spatial Object, as a measurement or estimate of one or more
dimensions
                  of the Spatial Object's spatial presence. Units are always metric
                  (meter, square meter or cubic meter)."@en ;
  skos:prefLabel "has metric size"@en ;
.

```

6.3.3. Property: `geo:hasLength`

The property `geo:hasLength` can be used to indicate the length of a Spatial Object if it is not possible to use the property `geo:hasMetricLength`. It is a subproperty of `geo:hasSize`.

```

geo:hasLength
  a rdf:Property, owl:ObjectProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf geo:hasSize ;
  skos:definition "The length of a Spatial Object."@en ;
  skos:prefLabel "has length"@en ;
.

```

6.3.4. Property: `geo:hasMetricLength`

The property `geo:hasMetricLength` can be used to indicate the length of a Spatial Object in meters (m). It is a subproperty of `geo:hasMetricSize`. This property can be used for Spatial Objects having one, two, or three dimensions.

```

geo:hasMetricLength
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf geo:hasMetricSize ;
  skos:definition "The length of a Spatial Object in meters."@en ;
  skos:prefLabel "has length in meters"@en ;
.

```

6.3.5. Property: `geo:hasPerimeterLength`

The property `geo:hasPerimeterLength` can be used to indicate the length of the outer boundary of a Spatial Object if it is not possible to use the property `geo:hasMetricPerimeterLength`. It is a subproperty of `geo:hasSize`.

```

geo:hasPerimeterLength
  a rdf:Property, owl:ObjectProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf geo:hasSize ;
  skos:definition "The length of the perimeter of a Spatial Object."@en ;
  skos:prefLabel "has perimeter length"@en ;
.

```

6.3.6. Property: `geo:hasMetricPerimeterLength`

The property `geo:hasMetricPerimeterLength` can be used to indicate the length of the outer boundary of a Spatial Object in meters (m). It is a subproperty of `geo:hasMetricSize`. Circumference is considered a type of perimeter, so this property can be used for circular or curved objects too. This property can be used for Spatial Objects having two or three dimensions.

```

geo:hasMetricPerimeterLength
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf geo:hasMetricSize ;
  skos:definition "The length of the perimeter of a Spatial Object in meters."@en ;
  skos:prefLabel "has perimeter length in meters"@en ;
.

```

TIP

A consistency check can be applied to Geometry instances indicating both this property and the property `geo:dimension`: if supplied, the `geo:dimension` property's range value must be the literal integer 2 or 3. The following SPARQL query will return `true` if applied to a graph where this is not the case for all Geometries:

```

PREFIX geo: <http://www.opengis.net/ont/geosparql#>
ASK
WHERE {
  ?g geo:hasMetricPerimeterLength ?p ;
     geo:dimension ?d .

  FILTER (?d < 2)
}

```

6.3.7. Property: `geo:hasArea`

The property `geo:hasArea` can be used to indicate the area of a Spatial Object if it is not possible to use the property `geo:hasMetricArea`. It is a subproperty of `geo:hasSize`.

```

geo:hasArea
  a rdf:Property, owl:ObjectProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf geo:hasSize ;
  skos:definition "The area of a Spatial Object."@en ;
  skos:prefLabel "has area"@en ;
.

```

6.3.8. Property: `geo:hasMetricArea`

The property `geo:hasMetricArea` can be used to indicate the area of a Spatial Object in square meters (m²). It is a subproperty of `geo:hasMetricSize`. This property can be used for Spatial Objects having two or three dimensions.

```

geo:hasMetricArea
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf geo:hasMetricSize ;
  skos:definition "The area of a Spatial Object in square meters."@en ;
  skos:prefLabel "has area in meters"@en ;
.

```

TIP

A consistency check can be applied to Geometry instances indicating both this property and the property `geo:dimension`: if supplied, the `geo:dimension` property's range value must be the literal integer 2 or 3. The following SPARQL query will return `true` if applied to a graph where this is not the case for all Geometries:

```

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

ASK
WHERE {
  ?g geo:hasMetricArea ?a ;
    geo:dimension ?d .

  FILTER (?d < 2)
}

```

6.3.9. Property: `geo:hasVolume`

The property `geo:hasVolume` can be used to indicate the volume of a Spatial Object if it is not possible to use the property `geo:hasMetricVolume`. It is a subproperty of `geo:hasSize`.

```

geo:hasVolume
  a rdf:Property, owl:ObjectProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf geo:hasSize ;
  skos:definition "The volume of a three-dimensional Spatial Object."@en ;
  skos:prefLabel "has volume"@en ;
.

```

6.3.10. Property: `geo:hasMetricVolume`

The property `geo:hasMetricVolume` can be used to indicate the volume of a Spatial Object in cubic meters (m³). It is a subproperty of `geo:hasMetricSize`. This property can be used for Spatial Objects having three dimensions.

```

geo:hasMetricVolume
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf :hasMetricSize ;
  skos:definition "The volume of a Spatial Object in cubic meters."@en ;
  skos:prefLabel "has area in meters"@en ;
.

```

TIP

A consistency check can be applied to Geometries indicating both this property and the property `geo:dimension`: if supplied, the property `geo:dimension` property's range value must be the literal integer 3. The following SPARQL query will return `true` if applied to a graph where this is not the case for all Geometries:

```

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

ASK
WHERE {
  ?g geo:hasMetricVolume ?v ;
    geo:dimension ?d .

  FILTER (?d != 3)
}

```

6.4. Standard Properties for geo:Feature

Properties are defined for associating `geo:Feature` instances with `geo:Geometry` instances.

Req 7 Implementations shall allow the properties `geo:hasGeometry`, `geo:hasDefaultGeometry`, `geo:hasCentroid` and `geo:hasBoundingBox` to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/feature-properties>

6.4.1. Property: geo:hasGeometry

The property `geo:hasGeometry` is used to link a Feature with a Geometry that represents its spatial extent. A given Feature may have many associated geometries.

```

geo:hasGeometry
  a rdf:Property, owl:ObjectProperty ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "has Geometry"@en ;
  skos:definition "A spatial representation for a given Feature."@en ;
  rdfs:domain geo:Feature;
  rdfs:range geo:Geometry ;
.

```

6.4.2. Property: `geo:hasDefaultGeometry`

The property `geo:hasDefaultGeometry` is used to link a Feature with its default Geometry. The default geometry is the Geometry that should be used for spatial calculations in the absence of a request for a specific geometry (e.g. in the case of query rewrite).

```
geo:hasDefaultGeometry
  a rdf:Property, owl:ObjectProperty ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "has Default Geometry"@en ;
  skos:definition "The default geometry to be used in spatial calculations,
                  usually the most detailed geometry."@en ;
  rdfs:subPropertyOf geo:hasGeometry;
  rdfs:domain geo:Feature;
  rdfs:range geo:Geometry ;
.
```

GeoSPARQL does not restrict the cardinality of the `has default geometry` property. It is thus possible for a Feature to have more than one distinct default geometry or to have no default geometry. This situation does not result in a query processing error; SPARQL graph pattern matching simply proceeds as normal. Certain queries may, however, give logically inconsistent results. For example, if a Feature `my:f1` has two asserted default geometries, and those two geometries are disjoint polygons, the query below could return a non-zero count on a system supporting the GeoSPARQL Query Rewrite Extension (rule `geor:sfDisjoint`).

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

SELECT (COUNT(*) AS ?cnt)
WHERE { :f1 geo:sfDisjoint :f1 }
```

Such cases are application-specific data modeling errors and are therefore outside of the scope of the GeoSPARQL specification., however it is recommended that multiple geometries indicated with `geo:hasDefaultGeometry` should be differentiated by `Geometry` class properties, perhaps relating to precision, SRS etc.

6.4.3. Property: `geo:hasBoundingBox`

The property `geo:hasBoundingBox` is used to link a Feature with a simplified geometry-representation corresponding to the envelope of its geometry. Bounding-boxes are typically uses in indexing and discovery.

```

geo:hasBoundingBox
  a rdf:Property, owl:ObjectProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf geo:hasGeometry;
  skos:prefLabel "has bounding box"@en ;
  skos:definition "The minimum or smallest bounding or enclosing box of a given
Feature."@en ;
  skos:scopeNote "The target is a geometry that defines a rectilinear region whose
edges are
                aligned with the axes of the coordinate reference system, which
exactly
                contains the geometry or Feature e.g. sf:Envelope"@en ;
  rdfs:domain geo:Feature ;
  rdfs:range geo:Geometry ;
.

```

GeoSPARQL does not restrict the cardinality of the `geo:hasBoundingBox` property. A Feature may be associated with more than one bounding-box, for example in different coordinate reference systems.

6.4.4. Property: `geo:hasCentroid`

The property `geo:hasCentroid` is used to link a Feature with a point geometry corresponding with the centroid of its geometry. The centroid is typically used to show location on a low-resolution image, and for some indexing and discovery functions.

```

geo:hasCentroid
  a rdf:Property, owl:ObjectProperty ;
  rdfs:isDefinedBy geo: ;
  rdfs:subPropertyOf geo:hasGeometry;
  skos:prefLabel "has centroid"@en ;
  skos:definition "The arithmetic mean position of all the geometry points
                of a given Feature."@en ;
  skos:scopeNote "The target geometry shall describe a point, e.g. sf:Point"@en ;
  rdfs:domain geo:Feature ;
  rdfs:range geo:Geometry ;
.

```

GeoSPARQL does not restrict the cardinality of the `geo:hasCentroid` property. A Feature may be associated with more than one centroid, for example computed using different rules or in different coordinate reference systems.

7. Topology Vocabulary Extension (relation_family)

This clause establishes the *Topology Vocabulary Extension (relation_family)* parameterized requirements class, with IRI [/req/topology-vocab-extension](#), which has a single corresponding conformance class *Topology Vocabulary Extension (relation_family)*, with IRI [/conf/topology-vocab-extension](#). This requirements class defines a vocabulary for asserting and querying topological relations between spatial objects. The class is parameterized so that different families of topological relations may be used, e.g. RCC8, Egenhofer. These relations are generalized so that they may connect features as well as geometries.

A Dimensionally Extended 9-Intersection Model (DE-9IM) pattern, which specifies the spatial dimension of the intersections of the interiors, boundaries and exteriors of two geometric objects, is used to describe each spatial relation. Possible pattern values are `-1 (empty)`, `0`, `1`, `2`, `T (true)` = `{0, 1, 2}`, `F (false)` = `{-1}`, `*` (don't care) = `{-1, 0, 1, 2}`. In the following descriptions, the notation `X/Y` is used denote applying a spatial relation to geometry types `X` and `Y` (i.e., `x relation y` where `x` is of type `X` and `y` is of type `Y`). The symbol `P` is used for 0-dimensional geometries (e.g. points). The symbol `L` is used for 1-dimensional geometries (e.g. lines), and the symbol `A` is used for 2-dimensional geometries (e.g. polygons). Consult the Simple Features specification [\[ISO19125-1\]](#) for a more detailed description of DE-9IM intersection patterns.

7.1. Parameters

The following parameter is defined for the *Topology Vocabulary Extension* requirements class.

relation_family: Specifies the set of topological spatial relations to support.

7.2. Simple Features Relation Family (relation_family=Simple Features)

This clause defines requirements for the *Simple Features* relation family.

Req 8 Implementations shall allow the properties `geo:sfEquals`, `geo:sfDisjoint`, `geo:sfIntersects`, `geo:sfTouches`, `geo:sfCrosses`, `geo:sfWithin`, `geo:sfContains` and `geo:sfOverlaps` to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.0/req/topology-vocab-extension/sf-spatial-relations>

Topological relations in the *Simple Features* family are summarized in [Table 2](#). Multi-row intersection patterns should be interpreted as a logical **OR** of each row.

Table 2. Simple Features Topological Relations

| Relation Name | Relation IRI | Domain/Range | Applies To Geometry Types | DE-9IM Intersection Pattern |
|---------------|---------------------------|--------------------------------|---------------------------|-----------------------------|
| equals | <code>geo:sfEquals</code> | <code>geo:SpatialObject</code> | All | (TFFFTFFFT) |

| Relation Name | Relation IRI | Domain/Range | Applies To Geometry Types | DE-9IM Intersection Pattern |
|---------------|----------------------------------|-----------------------------------|---------------------------|--|
| disjoint | geo:sfDisjoint | geo:SpatialObject | All | (FF**FF****) |
| intersects | geo:sfIntersects | geo:SpatialObject | All | (T***** *T***** ***T***** ****T****) |
| touches | geo:sfTouches | geo:SpatialObject | All except P/P | (FT***** F**T***** F***T****) |
| within | geo:sfWithin | geo:SpatialObject | All | (T*F**F****) |
| contains | geo:sfContains | geo:SpatialObject | All | (T*****F*) |
| overlaps | geo:sfOverlaps | geo:SpatialObject | A/A, P/P, L/L | (T*T***T**) for A/A, P/P; (1*T***T**) for L/L |
| crosses | geo:sfCrosses | geo:SpatialObject | P/L, P/A, L/A, L/L | (T*T***T**) for P/L, P/A, L/A; (0*****F*) for L/L |

7.3. Egenhofer Relation Family (`relation_family=Egenhofer`)

This clause defines requirements for the 9-intersection model for binary topological relations (*Egenhofer*) relation family. Consult references [\[FORMAL\]](#) and [\[CATEG\]](#) for a more detailed discussion of *Egenhofer* relations.

Req 9 Implementations shall allow the properties [geo:ehEquals](#), [geo:ehDisjoint](#), [geo:ehMeet](#), [geo:ehOverlap](#), [geo:ehCovers](#), [geo:ehCoveredBy](#), [geo:ehInside](#) and [geo:ehContains](#) to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.0/req/topology-vocab-extension/eh-spatial-relations>

Topological relations in the *Egenhofer* family are summarized in [\[egenhofer_relations\]](#). Multi-row intersection patterns should be interpreted as a logical **OR** of each row.

Table 3. *Egenhofer* Topological Relations

| Relation Name | Relation IRI | Domain/Range | Applies To Geometry Types | DE-9IM Intersection Pattern |
|---------------|--------------------------------|-----------------------------------|---------------------------|-----------------------------|
| equals | geo:ehEquals | geo:SpatialObject | All | (TFFFTFFFT) |
| disjoint | geo:ehDisjoint | geo:SpatialObject | All | (FF*FF****) |

| Relation Name | Relation IRI | Domain/Range | Applies To Geometry Types | DE-9IM Intersection Pattern |
|---------------|-----------------|-------------------|---------------------------|-------------------------------------|
| meet | geo:ehMeet | geo:SpatialObject | All except P/P | (FT***** F**T***** F***T****) |
| overlap | geo:ehOverlap | geo:SpatialObject | All | (T*T***T**) |
| covers | geo:ehCovers | geo:SpatialObject | A/A, A/L, L/L | (T*TFT*FF*) |
| covered by | geo:ehCoveredBy | geo:SpatialObject | A/A, L/A, L/L | (TFF*TFT**) |
| inside | geo:ehInside | geo:SpatialObject | All | (TFF*FFT**) |
| contains | geo:ehContains | geo:SpatialObject | All | (T*TFF*FF*) |

7.4. RCC8 Relation Family (relation_family=RCC8)

This clause defines requirements for the region connection calculus basic 8 (*RCC8*) relation family. Consult references [QUAL] and [LOGIC] for a more detailed discussion of *RCC8* relations.

Req 10 Implementations shall allow the properties `geo:rcc8eq`, `geo:rcc8dc`, `geo:rcc8ec`, `geo:rcc8po`, `geo:rcc8tppi`, `geo:rcc8tpp`, `geo:rcc8ntpp`, `geo:rcc8ntppi` to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.0/req/topology-vocab-extension/rcc8-spatial-relations>

Topological relations in the *RCC8* family are summarized in Table 4.

Table 4. *RCC8* Topological Relations

| Relation Name | Relation IRI | Domain/Range | Applies To Geometry Types | DE-9IM Intersection Pattern |
|------------------------------------|---------------|-------------------|---------------------------|-----------------------------|
| equals | geo:rcc8eq | geo:SpatialObject | A/A | (TFFFTFFFT) |
| disconnected | geo:rcc8dc | geo:SpatialObject | A/A | (FFTFFTTTT) |
| externally connected | geo:rcc8ec | geo:SpatialObject | A/A | (FFTFTTTTT) |
| partially overlapping | geo:rcc8po | geo:SpatialObject | A/A | (TTTTTTTTT) |
| tangential proper part inverse | geo:rcc8tppi | geo:SpatialObject | A/A | (TTTFTTFFT) |
| tangential proper part | geo:rcc8tpp | geo:SpatialObject | A/A | (TFFTFTTTT) |
| non-tangential proper part | geo:rcc8ntpp | geo:SpatialObject | A/A | (TFFTFFTTT) |
| non-tangential proper part inverse | geo:rcc8ntppi | geo:SpatialObject | A/A | (TTTFFTFFT) |

7.5. Equivalent RCC8, Egenhofer and Simple Features Topological Relations

Table 5 summarizes the equivalences between *Egenhofer*, *RCC8* and *Simple Features* spatial relations for closed, non-empty regions. The symbol + denotes logical OR, and the symbol ¬ denotes negation.

Table 5. Equivalent Simple Features, RCC8 and Egenhofer relations

| Simple Features | RCC8 | Egenhofer |
|-----------------|---|--------------------|
| equals | equals | equals |
| 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 |

8. Geometry Extension (serialization, version)

This clause establishes the *Geometry Extension (serialization, version)* parameterized requirements class, with IRI `/req/geometry-extension`, which has a single corresponding conformance class *Geometry Extension (serialization, version)*, with IRI `/conf/geometry-extension`. This requirements class defines a vocabulary for asserting and querying information about geometry data, and it defines query functions for operating on geometry data.

As part of the vocabulary, an RDFS datatype is defined for encoding detailed geometry information as a literal value. A literal representation of a geometry is needed so that geometric values may be treated as a single unit. Such a representation allows geometries to be passed to external functions for computations and to be returned from a query.

Other schemes for encoding simple geometry data in RDF have been implemented. The W3C Basic Geo vocabulary^[3] was an early (2003) RDF vocabulary for "representing lat(itude), long(itude) and other information about spatially-located things, using WGS84 as a reference datum" and many widely used Semantic Web vocabularies contain some spatial data support. For example, *Dublin Core Terms* provides a *Location* class^[4] for "A spatial region or named place." and *schema.org* provides a number of spatial object and geometry classes, such as *GeoCoordinates*^[5] and *GeoShape*^[6].

Many vocabularies, such as these two, provide little specific support for detailed geometries and only support the WGS84 Coordinate Reference System (CSR).

Since 2012 and the first version of GeoSPARQL, many ontologies have imported GeoSPARQL, for example, the *ISA Programme Location Core Vocabulary*^[7] whose usage notes provide examples containing GeoSPARQL literals and the use of GeoSPARQL's "geometry class". The W3C's more recent *Data Catalog Vocabulary, Version 2* (DCAT2) standard^[8] similarly contains usage notes for *geometry*, *bbox* and other properties that suggest the use of GeoSPARQL literals.

Some of the properties defined in these vocabularies, such as DCAT2's *spatialResolution* have motivated the inclusion of new properties in this version of GeoSPARQL. In this case the equivalent property is *geo:hasSpatialResolution*. The GeoSPARQL 1.1 Standards Working Group charter [CHARTER] contains references to a number of vocabularies/ontologies that were influential in the generation of this version of GeoSPARQL.

8.1. Parameters

The following parameters are defined for the *Geometry Extension* requirements class.

serialization

Specifies the serialization standard to use when generating geometry literals and also the supported geometry types.

NOTE

a serialization strongly affects the geometry conceptualization. The WKT serialization aligns the geometry types with *ISO 19125 Simple Features* [ISO19125-1], and the GML serialization aligns the geometry types with *ISO 19107 Spatial Schema* [ISO19107].

version

Specifies the version of the serialization format used.

8.2. Geometry Class

A single root geometry class is defined: **geo:Geometry**. In addition, properties are defined for describing geometry data and for associating geometries with features.

One container class is defined: **Geometry Collection**.

8.2.1. Class: geo:Geometry

The class **geo:Geometry** is equivalent to **GM_Object** [ISO19107] and is defined by the following:

```
geo:Geometry
  a rdfs:Class, owl:Class ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "Geometry"@en ;
  rdfs:subClassOf geo:SpatialObject ;
  owl:disjointWith geo:Feature;
  skos:definition "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 ;
.
```

Req 11 Implementations shall allow the RDFS class **geo:Geometry** to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/geometry-class>

8.2.2. Class: geo:GeometryCollection

The class **Geometry Collection** is defined by the following:

```

geo:GeometryCollection
  a owl:Class ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "Geometry Collection"@en ;
  skos:definition "The class Geometry Collection represents any collection of
individual Geometries."@en ;
  rdfs:subClassOf geo:SpatialObjectCollection ;
  rdfs:subClassOf [
    a owl:Restriction ;
    owl:allValuesFrom geo:Geometry ;
    owl:onProperty rdfs:member ;
  ] ;
.

```

The restriction imposed on the more general [Spatial Object Collection](#) that defines this class is that only instances of [Geometry](#) are allowed to be members of it and these are to be indicated with the [rdfs:member](#) property.

Req 12 Implementations shall allow the RDFS class [geo:GeometryCollection](#) to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.1/req/core/geometry-collection-class>

8.3. Standard Properties for geo:Geometry

Properties are defined for describing geometry metadata.

Req 13 Implementations shall allow the properties [geo:dimension](#), [geo:coordinateDimension](#), [geo:spatialDimension](#), [geo:hasSpatialResolution](#), [geo:hasMetricSpatialResolution](#), [geo:hasSpatialAccuracy](#), [geo:hasMetricSpatialAccuracy](#), [geo:isEmpty](#), [geo:isSimple](#) and [geo:hasSerialization](#) to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/geometry-properties>

8.3.1. Property: geo:dimension

The property [geo:dimension](#) is used to link the a Geometry object to its topological dimension, which must be less than or equal to the coordinate dimension. In non-homogeneous collections, this will return the largest topological dimension of the contained objects.

```

geo:dimension
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "dimension"@en ;
  skos:definition "The topological dimension of this geometric object, which
                  must be less than or equal to the coordinate dimension. In
                  non-homogeneous collections, this is the largest
                  topological dimension of the contained objects."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range xsd:integer ;
.

```

8.3.2. Property: `geo:coordinateDimension`

The property `geo:coordinateDimension` is defined to link a Geometry object to the dimension of direct positions (coordinate tuples) used in the Geometry's definition.

```

geo:coordinateDimension
  a rdf:Property, owl:DatatypeProperty;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "coordinate dimension"@en ;
  skos:definition "The number of measurements or axes needed to describe the
                  position of this Geometry in a coordinate system."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range xsd:integer ;
.

```

8.3.3. Property: `geo:spatialDimension`

The property `geo:spatialDimension` is defined to link a Geometry object to the dimension of the spatial portion of the direct positions (coordinate tuples) used in its serializations. If the direct positions do not carry a measure coordinate, this will be equal to the coordinate dimension.

```

geo:spatialDimension
  a rdf:Property, owl:DatatypeProperty;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "spatial dimension"@en ;
  skos:definition "The number of measurements or axes needed to describe the
                  spatial position of this Geometry in a coordinate system."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range xsd:integer ;
.

```

8.3.4. Property: `geo:hasSpatialResolution`

The property `geo:hasSpatialResolution` is defined to indicate spatial resolution of the elements

within a Geometry. Spatial resolution specifies the level of detail of a Geometry. It the smallest distinguishable distance between adjacent coordinate sets. Therefore this property is not applicable to a point Geometry, because it consists of a single coordinate set.

Since this property is defined for a `geo:Geometry`, all literal representations of that Geometry instance must have the same spatial resolution.

```
geo:hasSpatialResolution
  a rdf:Property, owl:ObjectProperty;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "has spatial resolution"@en ;
  skos:definition "The spatial resolution of a Geometry"@en ;
  rdfs:domain geo:Geometry ;
  .
```

8.3.5. Property: `geo:hasMetricSpatialResolution`

The property `geo:hasMetricSpatialResolution` is similar to `geo:hasSpatialResolution`, specifies that the unit of resolution distance is always meter (the standard distance unit of the International System of Units).

```
geo:hasMetricSpatialResolution
  a rdf:Property, owl:ObjectProperty;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "has spatial resolution in meters"@en ;
  skos:definition "The spatial resolution of a Geometry in meters."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range xsd:double ;
  .
```

8.3.6. Property: `geo:hasSpatialAccuracy`

The property `geo:hasSpatialAccuracy` is applicable when a Geometry is used to represent a Feature. It is expressed as a distance that indicates the truthfulness of the positions (coordinates) that define the Geometry. In this case accuracy defines a zone surrounding each coordinate within which the real positions are known to be. The accuracy value defines this zone as a distance from the coordinate(s) in all directions (e.g. a line, a circle or a sphere, depending on spatial dimension).

```
geo:hasSpatialAccuracy
  a rdf:Property, owl:ObjectProperty;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "has spatial accuracy"@en ;
  skos:definition "The positional accuracy of the coordinates of a Geometry."@en ;
  rdfs:domain geo:Geometry ;
  .
```

8.3.7. Property: `geo:hasMetricSpatialAccuracy`

The property `geo:hasMetricSpatialAccuracy` is similar to `has spatial accuracy`, but it is easier to specify and use because the unit of distance is always meter (the standard distance unit of the International System of Units).

```
geo:hasMetricSpatialAccuracy
  a rdf:Property, owl:ObjectProperty;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "has spatial accuracy in meters"@en ;
  skos:definition "The positional accuracy of the coordinates of a Geometry in
meters."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range xsd:double ;
.
```

8.3.8. Property: `geo:isEmpty`

The property `geo:isEmpty` will indicate a Boolean object set to `true` if and only if the Geometry contains no information.

```
geo:isEmpty
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "is empty"@en ;
  skos:definition "(true) if this geometric object is the empty Geometry. If
true, then this geometric object represents the empty point
set for the coordinate space."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range xsd:boolean ;
.
```

8.3.9. Property: `geo:isSimple`

The property `geo:isSimple` will indicate a Boolean object set to `true`, only if the Geometry contains no self-intersections, with the possible exception of its boundary.

```
geo:isSimple
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "is simple"@en ;
  skos:definition "(true) if this geometric object has no anomalous geometric
points, such as self intersection or self tangency."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range xsd:boolean ;
.
```

8.3.10. Property: `geo:hasSerialization`

The property `geo:hasSerialization` is defined to connect a Geometry with its text-based serialization (e.g., its WKT serialization).

```
geo:hasSerialization
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "has serialization"@en ;
  skos:definition "Connects a Geometry object with its text-based serialization."@en
;
  rdfs:domain geo:Geometry ;
  rdfs:range rdfs:Literal ;
.
```

NOTE

this property is the generic property used to connect a Geometry with its serialization. GeoSPARQL also contains a number of sub properties of this one for connecting serializations of common types with geometries, for example [as GeoJSON](#) which can be used for GeoJSON [\[GEOJSON\]](#) literals.

8.4. Geometry Serializations

This section establishes the requirements for representing Geometry data in RDF based on different systems.

8.4.1. Well-Known Text (serialization=WKT)

This section establishes the requirements for representing Geometry data in RDF based on Well-Known Text (WKT) as defined by Simple Features [\[ISO19125-1\]](#). It defines one RDFS Datatype: [WKT Literal](#) and one property, [as WKT](#).

8.4.1.1. RDFS Datatype: `geo:wktLiteral`

The datatype `geo:wktLiteral` is used to contain the Well-Known Text (WKT) serialization of a Geometry.

```
geo:wktLiteral
  a rdfs:Datatype ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "Well-known Text literal"@en ;
  skos:definition "A Well-known Text serialization of a Geometry object."@en ;
.
```

Req 14 All RDFS Literals of type `geo:wktLiteral` shall consist of an optional IRI identifying the coordinate reference system and a required Well Known Text (WKT) description of a geometric value. Valid `geo:wktLiteral` instances are formed by either a WKT string as defined in [ISO13249] or by concatenating a valid absolute IRI, as defined in [IETF3987], enclose in angled brackets (< & >) followed by a single space (Unicode U+0020 character) as a separator, and a WKT string as defined in [ISO13249].

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/wkt-literal>

The following *ABNF* [IETF5234] syntax specification formally defines this literal:

```
wktLiteral ::= opt-iri-and-space geometric-data
```

```
opt-iri-and-space = "<" IRI ">" LWSP / ""
```

The token `opt-iri-and-space` may be either an IRI and space or nothing (""), the token `IRI` (Internationalized Resource Identifier) is essentially a web address and is defined in [IETF3987] and the token `LWSP`, is one or more white space characters, as defined in [IETF5234]. `geometric-data` is the Well-Known Text representation of the Geometry, defined in [ISO13249].

In the absence of a leading spatial reference system IRI, the following spatial reference system IRI will be assumed: `<http://www.opengis.net/def/crs/OGC/1.3/CRS84>`. This IRI denotes WGS 84 longitude-latitude.

Req 15 The IRI `<http://www.opengis.net/def/crs/OGC/1.3/CRS84>` shall be assumed as the spatial reference system for `geo:wktLiteral` instances that do not specify an explicit spatial reference system IRI.

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/wkt-literal-default-srs>

The OGC maintains a set of SRS IRIs under the `http://www.opengis.net/def/crs/` namespace and IRIs from this set are recommended for use, however others may also be used, as long as they are valid IRIs.

Req 16 Coordinate tuples within `geo:wktLiteral` shall be interpreted using the axis order defined in the spatial reference system used.

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/wkt-axis-order>

The example `WKT Literal` below encodes a point Geometry using the default WGS84 geodetic longitude-latitude spatial reference system:

```
"Point(-83.38 33.95)"^^<http://www.opengis.net/ont/geosparql#wktLiteral>
```

A second example below encodes the same point as encoded in the example above but using a SRS identified by `http://www.opengis.net/def/SRS/EPSG/0/4326`: a WGS 84 geodetic latitude-longitude spatial reference system (note that this spatial reference system defines a different axis order):

```
"<http://www.opengis.net/def/crs/EPSG/0/4326> Point(33.95
-83.38)"^^<http://www.opengis.net/ont/geosparql#wktLiteral>
```

Req 17 An empty RDFS Literal of type `geo:wktLiteral` shall be interpreted as an empty Geometry.

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/wkt-literal-empty>

8.4.1.2. Property: `geo:asWKT`

The property `geo:asWKT` is defined to link a Geometry with its WKT serialization.

Req 18 Implementations shall allow the RDF property `geo:asWKT` to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/geometry-as-wkt-literal>

```
geo:asWKT
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:subPropertyOf geo:hasSerialization ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "as WKT"@en ;
  skos:definition "The WKT serialization of a Geometry."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range geo:wktLiteral ;
  .
```

8.4.1.3. Function: `geof:asWKT`

```
geof:asWKT (geom: ogc:geomLiteral): geo:wktLiteral
```

The function `geof:asWKT` converts `geom` to an equivalent WKT representation preserving the coordinate reference system.

Req 19 Implementations shall support `geo:asWKT` as a SPARQL extension function.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/asWKT-function>

8.4.2. Geography Markup Language (serialization=GML)

This section establishes requirements for representing Geometry data in RDF based on GML as defined by Geography Markup Language Encoding Standard [OGC07-036]. It defines one RDFS Datatype: `GML Literal` and one property, `as GML`.

8.4.2.1. RDFS Datatype: `geo:gmlLiteral`

The datatype `geo:gmlLiteral` is used to contain the Geography Markup Language (GML) serialization of a Geometry.

```

geo:gmlLiteral
  a rdfs:Datatype ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "GML literal"@en ;
  skos:definition "The datatype of GML literal values"@en ;
.

```

Valid **GML Literal** instances are formed by encoding Geometry information as a valid element from the GML schema that implements a subtype of **GM_Object**. For example, in GML 3.2.1 this is every element directly or indirectly in the substitution group of the element <http://www.opengis.net/ont/gml/3.2> **AbstractGeometry**. In GML 3.1.1 and GML 2.1.2 this is every element directly or indirectly in the substitution group of the element <http://www.opengis.net/ont/gml> **_Geometry**.

Req 20 All **geo:gmlLiteral** instances shall consist of a valid element from the GML schema that implements a subtype of **GM_Object** as defined in [\[OGC07-036\]](#).

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/gml-literal>

The example **GML Literal** below encodes a point Geometry in the WGS 84 geodetic longitude-latitude spatial reference system using GML version 3.2:

```

"""
<gml:Point
  srsName=\"http://www.opengis.net/def/crs/OGC/1.3/CRS84\"
  xmlns:gml=\"http://www.opengis.net/ont/gml\">
  <gml:pos>-83.38 33.95</gml:pos>
</gml:Point>
""""^<http://www.opengis.net/ont/geosparql#gmlLiteral>

```

Req 21 An empty **geo:gmlLiteral** shall be interpreted as an empty Geometry.

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/gml-literal-empty>

Req 22 Implementations shall document supported GML profiles.

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/gml-profile>

8.4.2.2. Property: geo:asGML

The property **geo:asGML** is defined to link a Geometry with its GML serialization.

Req 23 Implementations shall allow the RDF property **geo:asGML** to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/geometry-as-gml-literal>

```

geo:asGML
  a rdf:Property ;
  rdfs:subPropertyOf geo:hasSerialization ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "as GML"@en ;
  skos:definition "The GML serialization of a Geometry."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range geo:gmlLiteral ;
.

```

8.4.2.3. Function: **geof:asGML**

```
geof:asGML (geom: ogc:geomLiteral, gmlProfile: xsd:string): geo:gmlLiteral
```

The function **geof:asGML** converts **geom** to an equivalent GML representation defined by a **gmlProfile** version string preserving the coordinate reference system.

Req 24 Implementations shall support **geof:asGML** as a SPARQL extension function.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/asGML-function>

8.4.3. GeoJSON (serialization=GEOJSON)

This section establishes requirements for representing Geometry data in RDF based on GeoJSON as defined by [GeoJSON]. It defines one RDFS Datatype: **GeoJSON Literal** and one property, **as GeoJSON**.

8.4.3.1. RDFS Datatype: **geo:geoJSONLiteral**

The datatype **geo:geoJSONLiteral** is used to contain the Geo JavaScript Object Notation (GeoJSON) serialization of a Geometry.

```

geo:geoJSONLiteral a rdfs:Datatype ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "GeoJSON Literal"@en ;
  skos:definition "A GeoJSON serialization of a Geometry object."@en .

```

Valid **GeoJSON Literal** instances are formed by encoding Geometry information as a Geometry object as defined in the GeoJSON specification [GEOJSON].

Req 25 All **geo:geoJSONLiteral** instances shall consist of the Geometry objects as defined in the GeoJSON specification [GEOJSON].

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/geojson-literal>

Req 26 RDFS Literals of type `geo:geoJSONLiteral` do not contain a SRS definition. All literals of this type shall, according to the GeoJSON specification, be encoded only in, and be assumed to use, the WGS84 geodetic longitude-latitude spatial reference system (<http://www.opengis.net/def/crs/OGC/1.3/CRS84>).

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/geojson-literal-srs>

The example `GeoJSON Literal` below encodes a point Geometry using the default WGS84 geodetic longitude-latitude spatial reference system for Simple Features 1.0:

```
""
{"type": "Point", "coordinates": [-83.38,33.95]}
""^^<http://www.opengis.net/ont/geosparql#geoJSONLiteral>
```

Req 27 An empty RDFS Literal of type `geo:geoJSONLiteral` shall be interpreted as an empty Geometry, i.e. `{"geometry": null}` in GeoJSON .

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/geojson-literal-empty>

8.4.3.2. Property: `geo:asGeoJSON`

The property `geo:asGeoJSON` is defined to link a Geometry with its GeoJSON serialization.

Req 28 Implementations shall allow the RDF property `geo:asGeoJSON` to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/geometry-as-geojson-literal>

```
geo:asGeoJSON
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:subPropertyOf geo:hasSerialization ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "as GeoJSON"@en ;
  skos:definition "The GeoJSON serialization of a Geometry."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range geo:geoJSONLiteral ;
  .
```

8.4.3.3. Function: `geof:asGeoJSON`

```
geof:asGeoJSON (geom: ogc:geomLiteral): geo:geoJSONLiteral
```

The function `geof:asGeoJSON` converts `geom` to an equivalent GeoJSON representation. Coordinates are converted to the CRS84 coordinate system, the only valid coordinate system to be used in a GeoJSON literal.

Req 29 Implementations shall support `geof:asGeoJSON` as a SPARQL extension function.

8.4.4. Keyhole Markup Language (serialization=KML)

This section establishes requirements for representing Geometry data in RDF based on KML as defined by [OGCKML]. It defines one RDFS Datatype: **KML Literal** and one property, **as KML**.

8.4.4.1. RDFS Datatype: **geo:kmlLiteral**

The datatype **geo:kmlLiteral** is used to contain the Keyhole Markup Language (KML) serialization of a Geometry.

```
geo:kmlLiteral
  a rdfs:Datatype ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "KML Literal"@en ;
  skos:definition "A KML serialization of a Geometry object."@en ;
  .
```

Valid **KML Literal** instances are formed by encoding Geometry information as a Geometry object as defined in the KML specification [OGCKML].

Req 30 All **geo:kmlLiteral** instances shall consist of the Geometry objects as defined in the KML specification [OGCKML].

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/kml-literal>

Req 31 RDFS Literals of type **geo:kmlLiteral** do not contain a SRS definition. All literals of this type shall according to the KML specification only be encoded in and assumed to use the WGS84 geodetic longitude-latitude spatial reference system (<http://www.opengis.net/def/crs/OGC/1.3/CRS84>).

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/kml-literal-srs>

The example **KML Literal** below encodes a point Geometry using the default WGS84 geodetic longitude-latitude spatial reference system for Simple Features 1.0:

```
"""
<Point xmlns="http://www.opengis.net/kml/2.2">
  <coordinates>-83.38,33.95</coordinates>
</Point>
""'^<http://www.opengis.net/ont/geosparql#kmlLiteral>
```

Req 32 An empty RDFS Literal of type **geo:kmlLiteral** shall be interpreted as an empty Geometry .

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/kml-literal-empty>

8.4.4.2. Property: geo:asKML

The property **geo:asKML** is defined to link a Geometry with its KML serialization.

Req 33 Implementations shall allow the RDF property **geo:asKML** to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/geometry-as-kml-literal>

The property **as KML** is used to link a geometric element with its KML serialization.

```
geo:asKML
  a rdf:Property, owl:DatatypeProperty;
  rdfs:subPropertyOf geo:hasSerialization ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "as KML"@en ;
  skos:definition "The KML serialization of a Geometry."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range geo:kmlLiteral ;
  .
```

8.4.4.3. Function: geof:asKML

```
geof:asKML (geom: ogc:geomLiteral): geo:kmlLiteral
```

The function **geof:asKML** converts **geom** to an equivalent KML representation. Coordinates are converted to the CRS84 coordinate system, the only valid coordinate system to be used in a KML literal.

Req 34 Implementations shall support **geof:asKML** as a SPARQL extension function.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/asKML-function>

8.4.5. Discrete Global Grid System (serialization=DGGS)

This section establishes the requirements for representing Discrete Global Grid System (DGGS) Geometry data as RDF literals. The form of representation is specific to individual DGGS implementations: known DGGSes are not compatible or even very similar.

Here is defined one RDFS Datatypes: <http://www.opengis.net/ont/geosparql#dggsLiteral> and one property, <http://www.opengis.net/ont/geosparql#asDGGS>.

NOTE

The datatype defined here is for an abstract DGGS implementation (**DGGS Literal**) but concrete ones should be used in real implementations. For example, the AusPIX DGGS [\[AUSPIX\]](#) might implement something similar to **ex:auspixDggsLiteral**.

8.4.5.1. RDFS Datatype: `geo:dggsLiteral`

The datatype `geo:dggsLiteral` is used to contain the Discrete Global Grid System (DGGS) serialization of a Geometry.

```
geo:dggsLiteral
  a rdfs:Datatype ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "DGGS Literal"@en ;
  skos:definition "A textual serialization of a Discrete Global Grid System (DGGS)
  Geometry object."@en
  .
```

Valid `DGGS Literal` instances are formed by encoding Geometry information according to specific DGGS implementation. The specific implementation should be indicated by use of a subclass of the `geo:dggsLiteral` datatype.

Req 35 All RDFS Literals of type `geo:dggsLiteral` shall consist of a DGGS Geometry serialization formulated according to a specific DGGS.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/dggs-literal>

Req 36 An empty RDFS Literal of type `geo:dggsLiteral`, or one of its data subtypes, shall be interpreted as an empty `geo:Geometry`.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/dggs-literal-empty>

An example of a literal for concrete DGGS, AusPIX, could be

```
ex:auspixDggsLiteral
  a rdfs:Datatype ;
  skos:prefLabel "AusPIX DGGS Literal"@en ;
  skos:definition "A textual serialization of an AusPIX Discrete Global Grid System
  (DGGS) Geometry object."@en ;
  .
```

A single *Cell* Geometry encoded according to the AusPIX DGGS using the example literal above is given below. The single cell value of *R3234* is analogous to either a `Point` or simple `Polygon` in WKT geometries.

```
"CellList (R3234)"^^<http://example.com#auspixDggsLiteral>
```

NOTE

What `R3234` means, or the meaning of any other element within a concrete DGGS literal is not handled by GeoSPARQL but is expected to be handled by that DGGS' specification, just as GeoPSARQL does not delve into the internals of other Geometry formats such as WKT or GeoJSON.

8.4.5.2. Property: `geo:asDGGs`

The property `geo:asDGGs` is defined to link a Geometry with its DGGs serialization.

Req 38 Implementations shall allow the RDF property `geo:asDGGs` to be used in SPARQL graph patterns.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/geometry-as-dggs-literal>

```
geo:asDGGs
  a rdf:Property, owl:DatatypeProperty ;
  rdfs:subPropertyOf geo:hasSerialization ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "as DGGs"@en ;
  skos:definition "A DGGs serialization of a Geometry."@en ;
  rdfs:domain geo:Geometry ;
  rdfs:range geo:dggsLiteral ;
  .
```

NOTE

It is expected that this property will be used to indicate specific DGGs data types, such as the example `ex:auspidxDggsLiteral`, described above, as opposed to the generic `DGGs Literal`.

8.4.5.3. Function: `geof:asDGGs`

```
geof:asDGGs (geom: ogc:geomLiteral, specificDggsDatatype: xsd:anyURI): geo:DggsLiteral
```

The function `geof:asDGGs` converts `geom` to an equivalent DGGs representation, formulated according to the specific DGGs literal indicated using the `specificDggsDatatype` parameter.

Req 39 Implementations shall support `geof:asDGGs` as a SPARQL extension function.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/asDGGs-function>

8.5. Non-topological Query Functions

This clause defines SPARQL functions for performing non-topological spatial operations.

Req 40 Implementations shall support the functions `geof:distance`, `geof:buffer`, `geof:intersection`, `geof:union`, `geof:isEmpty`, `geof:isSimple`, `geof:area`, `geof:length`, `geof:numGeometries`, `geof:geometryN`, `geof:transform`, `geof:dimension`, `geof:difference`, `geof:symDifference`, `geof:envelope` and `geof:boundary` as SPARQL extension functions, consistent with the definitions of their corresponding functions in Simple Features [ISO19125-1] (`distance`, `buffer`, `intersection`, `union`, `isEmpty`, `isSimple`, `area`, `length`, `numGeometries`, `geometryN`, `transform`, `dimension`, `difference`, `symDifference`, `envelope` and `boundary` respectively) and other attached definitions and also `geof:maxX`, `geof:maxY`, `geof:maxZ`, `geof:minX`, `geof:minY` and `geof:minZ` SPARQL extension functions.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/query-functions>

An invocation of any of the following functions with invalid arguments produces an error. An invalid argument includes any of the following:

- An argument of an unexpected type
- An invalid geometry literal value
- An non-fitting geometry type for the given function
- A geometry literal from a spatial reference system that is incompatible with the spatial reference system used for calculations
- An invalid units IRI

A more detailed description of expected inputs and expected outputs of the given functions is shown in Annex B.

Unless otherwise stated in the function definition, the following behaviors should be followed by all SPARQL extension functions defined in the GeoSPARQL standard:

- Functions returning a new geometry literal should follow the literal format of the first geometry literal input parameter. If no geometry literal input parameter is present, a WKT literal shall be returned
- Functions returning a new geometry literal should follow the SRS defined in the literal format of the first geometry literal input parameter. If no geometry literal input parameter is present, a geometry result should be returned in the CRS84 coordinate reference system

For further discussion of the effects of errors during FILTER evaluation, consult Section 17^[9] of the SPARQL specification [SPARQL].

Note that returning values instead of raising an error serves as an extension mechanism of SPARQL.

From Section 17.3.1^[10] of the SPARQL specification [SPARQL]:

SPARQL language extensions may provide additional associations between operators and operator functions; ... No additional operator may yield a result that replaces any result other The consequence of this rule is that SPARQL **FILTER** s will produce at least the same intermediate bindings after applying a **FILTER** as an unextended implementation.

This extension mechanism enables GeoSPARQL implementations to simultaneously support multiple geometry serializations. For example, a system that supports **WKT Literal** serializations may also support **GML Literal** serializations and consequently would not raise an error if it encounters multiple geometry datatypes while processing a given query.

NOTE

Several non-topological query functions use a unit of measure IRI. The OGC has recommended units of measure vocabularies for use, see the OGC Definitions Server^[11].

8.5.1. Function: geof:distance

```
geof:distance (geom1: ogc:geomLiteral,  
              geom2: ogc:geomLiteral,  
              units: xsd:anyURI): xsd:double
```

Returns the shortest distance between any two Points in the two geometric objects. Calculations are in spatial reference system of **geom1**.

8.5.2. Function: geof:buffer

```
geof:buffer (geom: ogc:geomLiteral,  
            radius: xsd:double,  
            units: xsd:anyURI): ogc:geomLiteral
```

Returns a geometric object that represents all Points whose distance from **geom1** is less than or equal to the **radius** measured in **units**. Calculations are in the spatial reference system of **geom1**.

8.5.3. Function: geof:isEmpty

```
geof:isEmpty (geom1: ogc:geomLiteral): xsd:boolean
```

Returns true if **geom1** is an empty geometry, i.e. contains no coordinates.

8.5.4. Function: geof:isSimple

```
geof:isSimple (geom1: ogc:geomLiteral): xsd:boolean
```

Returns true if **geom1** is a simple geometry, i.e. has no anomalous geometric points, such as self intersection or self tangency.

8.5.5. Function: geof:area

```
geof:area (geom1: ogc:geomLiteral): xsd:double
```

Returns the area of **geom1** in squaremeters.

8.5.6. Function: geof:length

```
geof:length (geom1: ogc:geomLiteral): xsd:double
```

Returns the length of **geom1** in meters.

8.5.7. Function: geof:dimension

```
geof:dimension (geom1: ogc:geomLiteral): xsd:integer
```

Returns the dimension of **geom1**.

8.5.8. Function: geof:numGeometries

```
geof:numGeometries (geom1: ogc:geomLiteral): xsd:integer
```

Returns the number of geometries of **geom1**.

8.5.9. Function: geof:geometryN

```
geof:geometryN (geom1: ogc:geomLiteral): xsd:integer
```

Returns the nth geometry of **geom1** if it is a GeometryCollection .

8.5.10. Function: geof:transform

```
geof:transform (geom: ogc:geomLiteral, srsIRI: xsd:anyURI): ogc:geomLiteral
```

geof:transform converts **geom** to a spatial reference system defined by srsIRI. The function raises an error if a transformation is not mathematically possible.

NOTE

We recommend that implementers use the same literal type as a result of this function that is passed as a parameter to this function.

8.5.11. Function: geof:intersection

```
geof:intersection (geom1: ogc:geomLiteral,  
                  geom2: ogc:geomLiteral): ogc:geomLiteral
```

Returns a geometric object that represents all Points in the intersection of **geom1** with **geom2**. Calculations are in the spatial reference system of **geom1**.

8.5.12. Function: geof:union

```
geof:union (geom1: ogc:geomLiteral,  
           geom2: ogc:geomLiteral): ogc:geomLiteral
```

This function returns a geometric object that represents all Points in the union of **geom1** with **geom2**.

Calculations are in the spatial reference system of **geom1**.

8.5.13. Function: **geof:difference**

```
geof:difference (geom1: ogc:geomLiteral,  
                geom2: ogc:geomLiteral): ogc:geomLiteral
```

This function returns a geometric object that represents all Points in the set difference of **geom1** with **geom2**. Calculations are in the spatial reference system of **geom1**.

8.5.14. Function: **geof:symDifference**

```
geof:symDifference (geom1: ogc:geomLiteral,  
                  geom2: ogc:geomLiteral): ogc:geomLiteral
```

This function returns a geometric object that represents all Points in the set symmetric difference of **geom1** with **geom2**. Calculations are in the spatial reference system of **geom1**.

8.5.15. Function: **geof:envelope**

```
geof:envelope (geom1: ogc:geomLiteral): ogc:geomLiteral
```

This function returns the minimum bounding box - a rectangle - of **geom1**. Calculations are in the spatial reference system of **geom1**.

8.5.16. Function: **geof:boundary**

```
geof:boundary (geom1: ogc:geomLiteral): ogc:geomLiteral
```

This function returns the closure of the boundary of **geom1**. Calculations are in the spatial reference system of **geom1**.

8.5.17. Function: **geof:convexHull**

```
geof:convexHull (geom1: ogc:geomLiteral): ogc:geomLiteral
```

The function **geof:convexHull** returns a geometric object that represents all Points in the convex hull of **geom1**. Calculations are in the spatial reference system of **geom1**.

8.5.18. Function: **geof:maxX**

```
geof:maxX (geom: ogc:geomLiteral): xsd:double
```


The function `geof:maxX` returns the maximum X coordinate for `geom`.

8.5.19. Function: `geof:maxY`

```
geof:maxY (geom: ogc:geomLiteral): xsd:double
```

The function `geof:maxY` returns the maximum Y coordinate for `geom`.

8.5.20. Function: `geof:maxZ`

```
geof:maxZ (geom: ogc:geomLiteral): xsd:double
```

The function `geof:maxZ` returns the maximum Z coordinate for `geom`.

8.5.21. Function: `geof:minX`

```
geof:minX (geom: ogc:geomLiteral): xsd:double
```

The function `geof:minX` returns the minimum X coordinate for `geom`.

8.5.22. Function: `geof:minY`

```
geof:minY (geom: ogc:geomLiteral): xsd:double
```

The function `geof:minY` returns the minimum Y coordinate for `geom`.

8.5.23. Function: `geof:minZ`

```
geof:minZ (geom: ogc:geomLiteral): xsd:double
```

The function `geof:minZ` returns the minimum Z coordinate for `geom`.

8.5.24. Function: `geof:getSRID`

```
geof:getSRID (geom: ogc:geomLiteral): xsd:anyURI
```

Returns the spatial reference system IRI for `geom`.

Req 41 Implementations shall support `geof:getSRID` as a SPARQL extension function.

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-extension/srid-function>

8.6. Spatial Aggregate Functions

This clause defines SPARQL functions for performing spatial aggregations of data.

Req 42 Implementations shall support `geof:aggBoundingBox`, `geof:aggBoundingCircle`, `geof:aggCentroid`, `geof:aggConcatLines`, `geof:aggConcaveHull`, `geof:aggConvexHull` and `geof:aggUnion` as a SPARQL extension functions.

<http://www.opengis.net/spec/geosparql/1.1/req/geometry-extension/sa-functions>

8.6.1. Function: `geof:aggBoundingBox`

```
geof:aggBoundingBox (geom: ogc:geomLiteral): ogc:geomLiteral
```

The function `geof:aggBoundingBox` calculates a minimum bounding box - rectangle - of the set of given geometries.

8.6.2. Function: `geof:aggBoundingCircle`

```
geof:aggBoundingCircle (geom: ogc:geomLiteral): ogc:geomLiteral
```

The function `geof:aggBoundingCircle` calculates a minimum bounding circle of the set of given geometries.

8.6.3. Function: `geof:aggCentroid`

```
geof:aggCentroid (geom: ogc:geomLiteral): ogc:geomLiteral
```

The function `geof:aggCentroid` calculates the centroid of the set of given geometries.

8.6.4. Function: `geof:aggConcatLines`

```
geof:aggConcatLines (geom: ogc:geomLiteral): ogc:geomLiteral
```

The function `geof:aggConcatLines` Concatenates a set of LineStrings.

8.6.5. Function: `geof:aggConcaveHull`

```
geof:aggConcaveHull (geom: ogc:geomLiteral, targetPercent: xsd:double):  
ogc:geomLiteral
```

The function `geof:aggConcaveHull` calculates the concave hull of the set of given geometries.

8.6.6. Function: **geof:aggConvexHull**

```
geof:aggConvexHull (geom: ogc:geomLiteral): ogc:geomLiteral
```

The function **geof:aggConvexHull** calculates the convex hull of the set of given geometries.

NOTE

This function is similar in name to [geof:aggConvexHull](#) used to calculate the convex hull of just one geometry.

8.6.7. Function: **geof:aggUnion**

```
geof:aggUnion (geom: ogc:geomLiteral): ogc:geomLiteral
```

The function **geof:aggUnion** calculates the union of the set of given geometries.

NOTE

This function is similar in name to [geof:aggUnion](#) used to calculate the union of just two geometries.

[3] <http://www.w3.org/2003/01/geo/>

[4] <http://purl.org/dc/terms/Location>

[5] <https://schema.org/GeoCoordinates>

[6] <https://schema.org/GeoShape>

[7] <https://www.w3.org/ns/locn>

[8] <https://www.w3.org/TR/vocab-dcat/#spatial-properties>

[9] <https://www.w3.org/TR/sparql11-query/#expressions>

[10] <https://www.w3.org/TR/sparql11-query/#operatorExtensibility>

[11] <https://www.ogc.org/def-server>

9. Geometry Topology Extension (`relation_family`, `serialization`, `version`)

This clause establishes the *Geometry Topology Extension* (`relation_family`, `serialization`, `version`) parameterized requirements class, with IRI [`/req/geometry-topology-extension`](#), which defines a collection of topological query functions that operate on geometry literals. This class is parameterized to give implementations flexibility in the topological relation families and geometry serializations that they choose to support. This requirements class has a single corresponding conformance class *Geometry Topology Extension* (`relation_family`, `serialization`, `version`), with IRI [`/conf/geometry-topology-extension`](#).

The Dimensionally Extended Nine Intersection Model (DE-9IM) [\[DE-9IM\]](#) has been used to define the relation tested by the query functions introduced in this section. Each query function is associated with a defining DE-9IM intersection pattern. Possible pattern values are:

- `-1` (empty)
- `0, 1, 2, T` (true) = `{0, 1, 2}`
- `F` (false) = `{-1}`
- `*` (don't care) = `{-1, 0, 1, 2}`

In the following descriptions, the notation `X/Y` is used denote applying a spatial relation to geometry types `X` and `Y` (i.e., `x relation y` where `x` is of type `X` and `y` is of type `Y`). The symbol `P` is used for 0-dimensional geometries (e.g. points). The symbol `L` is used for 1- dimensional geometries (e.g. lines), and the symbol `A` is used for 2-dimensional geometries (e.g. polygons). Consult the Simple Features specification [\[ISO19125-1\]](#) for a more detailed description of DE-9IM intersection patterns.

9.1. Parameters

- **`relation_family`**: Specifies the set of topological spatial relations to support.
- **`serialization`**: Specifies the serialization standard to use for geometry literals.
- **`version`**: Specifies the version of the serialization format used.

9.2. Common Query Functions

Req 43 Implementations shall support `geof:relate` as a SPARQL extension function, consistent with the `relate` operator defined in Simple Features [\[ISO19125-1\]](#).

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-topology-extension/relate-query-function>

```
geof:relate (geom1: ogc:geomLiteral,  
            geom2: ogc:geomLiteral,  
            pattern-matrix: xsd:string): xsd:boolean
```

Returns **true** if the spatial relationship between **geom1** and **geom2** corresponds to one with acceptable values for the specified pattern-matrix. Otherwise, this function returns **false**. **pattern-matrix** represents a DE-9IM intersection pattern consisting of **T** (true) and **F** (false) values. The spatial reference system for **geom1** is used for spatial calculations.

9.3. Simple Features Relation Family (**relation_family=Simple Features**)

This clause establishes requirements for the *Simple Features* relation family.

Req 44 Implementations shall support **geof:sfEquals**, **geof:sfDisjoint**, **geof:sfIntersects**, **geof:sfTouches**, **geof:sfCrosses**, **geof:sfWithin**, **geof:sfContains** and **geof:sfOverlaps** as SPARQL extension functions, consistent with their corresponding DE-9IM intersection patterns, as defined by Simple Features [ISO19125-1].

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-topology-extension/sf-query-functions>

Boolean query functions defined for the Simple Features relation family, along with their associated DE-9IM intersection patterns, are shown in Table 6 below. Multi-row intersection patterns should be interpreted as a logical OR of each row. Each function accepts two arguments (**geom1** and **geom2**) of the geometry literal *serialization* type *specified* by serialization and version. Each function returns an **xsd:boolean** value of **true** if the specified relation exists between **geom1** and **geom2** and returns false otherwise. In each case, the spatial reference system of **geom1** is used for spatial calculations.

Table 6. Simple Features Query Functions

| Query Function | Defining DE-9IM Intersection Pattern |
|--|--|
| geof:sfEquals (geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean | (TFFFTFFFT) |
| geof:sfDisjoint (geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean | (FF*FF****) |
| geof:sfIntersects (geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean | (FT***** F**T***** F***T*****) |
| geof:sfTouches (geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean | (FT***** F**T***** F***T*****) |
| geof:sfCrosses (geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean | (T*T***T**) for P/L, P/A, L/A; (0*T***T**) for L/L |
| geof:sfWithin (geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean | (T*F**F****) |
| geof:sfContains (geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean | (T*****FF*) |
| geof:sfOverlaps (geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean | (T*T***T**) for A/A, P/P; (1*T***T**) for L/L |

9.4. Egenhofer Relation Family (`relation_family=Egenhofer`)

This clause establishes requirements for the *Egenhofer* relation family. Consult references [FORMAL] and [CATEG] for a more detailed discussion of *Egenhofer* relations.

Req 45 Implementations shall support `geof:ehEquals`, `geof:ehDisjoint`, `geof:ehMeet`, `geof:ehOverlap`, `geof:ehCovers`, `geof:ehCoveredBy`, `geof:ehInside` and `geof:ehContains` as SPARQL extension functions, consistent with their corresponding DE-9IM intersection patterns, as defined by Simple Features [ISO19125-1].

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-topology-extension/eh-query-functions>

Boolean query functions defined for the *Egenhofer* relation family, along with their associated DE-9IM intersection patterns, are shown in Table 7 below. Multi-row intersection patterns should be interpreted as a logical OR of each row. Each function accepts two arguments (`geom1` and `geom2`) of the geometry literal serialization type specified by *serialization* and *version*. Each function returns an `xsd:boolean` value of `true` if the specified relation exists between `geom1` and `geom2` and returns `false` otherwise. In each case, the spatial reference system of `geom1` is used for spatial calculations.

Table 7. Egenhofer Query Functions

| Query Function | Defining DE-9IM Intersection Pattern |
|--|--------------------------------------|
| <code>geof:ehEquals(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (TFFFTFFFT) |
| <code>geof:ehDisjoint(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (FF*FF****) |
| <code>geof:ehMeet(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (FT***** F**T***** F***T****) |
| <code>geof:ehOverlap(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (T*T***T**) |
| <code>geof:ehCovers(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (T*TFT*FF*) |
| <code>geof:ehCoveredBy(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (TFF*TFT**) |
| <code>geof:ehInside(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (TFF*FFT**) |
| <code>geof:ehContains(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (T*TFF*FF*) |

9.5. Requirements for RCC8 Relation Family (`relation_family=RCC8`)

This clause establishes requirements for the *RCC8* relation family. Consult references [QUAL] and [LOGIC] for a more detailed discussion of *RCC8* relations.

Req 46 Implementations shall support `geof:rcc8eq`, `geof:rcc8dc`, `geof:rcc8ec`, `geof:rcc8po`, `geof:rcc8tppi`, `geof:rcc8tpp`, `geof:rcc8ntpp` and `geof:rcc8ntppi` as SPARQL extension functions, consistent with their corresponding DE-9IM intersection patterns, as defined by Simple Features [ISO19125-1].

<http://www.opengis.net/spec/geosparql/1.0/req/geometry-topology-extension/rcc8-query-functions>

Boolean query functions defined for the *RCC8* relation family, along with their associated DE-9IM intersection patterns, are shown in Table 8 below. Each function accepts two arguments (*geom1* and *geom2*) of the geometry literal serialization type specified by *serialization* and *version*. Each function returns an `xsd:boolean` value of `true` if the specified relation exists between *geom1* and *geom2* and returns `false` otherwise. In each case, the spatial reference system of *geom1* is used for spatial calculations.

Table 8. *RCC8* Query Functions

| Query Function | Defining DE-9IM Intersection Pattern |
|--|--------------------------------------|
| <code>geof:rcc8eq(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (TFFFTFFFT) |
| <code>geof:rcc8dc(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (FFTFFTTTT) |
| <code>geof:rcc8ec(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (FFTFTTTTT) |
| <code>geof:rcc8po(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (TTTTTTTTT) |
| <code>geof:rcc8tppi(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (TTFTTFFFT) |
| <code>geof:rcc8tpp(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (TFFTFTTTT) |
| <code>geof:rcc8ntpp(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (TFFTFFTTT) |
| <code>geof:rcc8ntppi(geom1: ogc:geomLiteral, geom2: ogc:geomLiteral): xsd:boolean</code> | (TTFTFTFFFT) |

10. RDFS Entailment Extension (`relation_family`, `serialization`, `version`)

This clause establishes the *RDFS Entailment Extension* (`relation_family`, `serialization`, `version`) parameterized requirements class, with IRI `/req/rdfs-entailment-extension`, which defines a mechanism for matching implicitly-derived RDF triples in GeoSPARQL queries. This class is parameterized to give implementations flexibility in the topological relation families and geometry types that they choose to support. This requirements class has a single corresponding conformance class *RDFS Entailment Extension* (`relation_family`, `serialization`, `version`), with IRI `/conf/rdfs-entailment-extension`.

10.1. Parameters

- **`relation_family`**: Specifies the set of topological spatial relations to support.
- **`serialization`**: Specifies the serialization standard to use for geometry literals.
- **`version`**: Specifies the version of the serialization format used.

10.2. Common Requirements

The basic mechanism for supporting RDFS entailment has been defined by the W3C SPARQL 1.1 RDFS Entailment Regime [\[SPARQLENT\]](#).

Req 47 Basic graph pattern matching shall use the semantics defined by the RDFS Entailment Regime [\[SPARQLENT\]](#).

<http://www.opengis.net/spec/geosparql/1.0/req/rdfs-entailment-extension/bgp-rdfs-ent>

10.3. WKT Serialization (`serialization=WKT`)

This section establishes the requirements for representing geometry data in RDF based on WKT as defined by Simple Features [\[ISO19125-1\]](#).

10.3.1. Geometry Class Hierarchy

The Simple Features specification presents a geometry class hierarchy. It is straightforward to represent this class hierarchy in RDFS and OWL by constructing IRIs for geometry classes using the following pattern: `http://www.opengis.net/ont/sf#{geometry class}` and by asserting appropriate `rdfs:subClassOf` statements.

The example RDF snippet below encodes the Polygon class from Simple Features 1.0.


```

sf:Polygon
  a rdfs:Class, owl:Class ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "Polygon"@en ;
  rdfs:subClassOf sf:Surface ;
  skos:definition "A planar surface defined by 1 exterior boundary and 0 or
                  more interior boundaries"@en ;
.

```

Req 48 Implementations shall support graph patterns involving terms from an RDFS/OWL class hierarchy of geometry types consistent with the one in the specified version of Simple Features [ISO19125-1].

<http://www.opengis.net/spec/geosparql/1.0/req/rdfs-entailment-extension/wkt-geometry-types>

10.4. GML Serialization (serialization=GML)

This section establishes requirements for representing geometry data in RDF based on GML as defined by Geography Markup Language Encoding Standard [OGC07-036].

10.4.1. Geometry Class Hierarchy

An RDF/OWL class hierarchy can be generated from the GML schema that implements **GM_Object** by constructing IRIs for geometry classes using the following pattern: <http://www.opengis.net/ont/gml#{GML Element}> and by asserting appropriate **rdfs:subClassOf** statements.

The example RDF snippet below encodes the Polygon class from GML 3.2.

```

gml:Polygon
  a rdfs:Class, owl:Class ;
  rdfs:isDefinedBy geo: ;
  skos:prefLabel "Polygon"@en ;
  rdfs:subClassOf gml:SurfacePatch ;
  skos:definition "A planar surface defined by 1 exterior boundary and 0 or
                  more interior boundaries."@en ;
.

```

Req 49 Implementations shall support graph patterns involving terms from an RDFS/OWL class hierarchy of geometry types consistent with the GML schema that implements **GM_Object** using the specified version of GML [OGC07-036].

<http://www.opengis.net/spec/geosparql/1.0/req/rdfs-entailment-extension/gml-geometry-types>

11. Query Rewrite Extension

(relation_family, serialization, version)

This clause establishes the *Query Rewrite Extension (relation_family, serialization, version)* parameterized requirements class, with IRI [/req/query-rewrite-extension](#), which has a single corresponding conformance class *Query Rewrite Extension (relation_family, serialization, version)*, with IRI [/conf/query-rewrite-extension](#). This requirements class defines a set of RIF rules [RIF] that use topological extension functions defined in Clause 9 to establish the existence of direct topological predicates defined in Clause 7. One possible implementation strategy is to transform a given query by expanding a triple pattern involving a direct spatial predicate into a series of triple patterns and an invocation of the corresponding extension function as specified in the RIF rule.

The following rule specified using the RIF Core Dialect [RIFCORE] is used as a template to describe rules in the remainder of this clause. `ogc:relation` is used as a placeholder for the spatial relation IRIs defined in Clause 7, and `ogc:function` is used as a placeholder for the spatial functions defined in Clause 9.

```
Forall ?f1 ?f2 ?g1 ?g2 ?g1Serial ?g2Serial
  (?f1[ogc:relation->?f2] :-
    Or(
      And
        # feature - feature rule
        (?f1[geo:hasDefaultGeometry->?g1]
         ?f2[geo:hasDefaultGeometry->?g2]
         ?g1[ogc:asGeomLiteral->?g1Serial]
         ?g2[ogc:asGeomLiteral->?g2Serial]
         External(ogc:function (?g1Serial,?g2Serial)))
      And
        # feature - geometry rule
        (?f1[geo:hasDefaultGeometry->?g1]
         ?g1[ogc:asGeomLiteral->?g1Serial]
         ?f2[ogc:asGeomLiteral->?g2Serial]
         External(ogc:function (?g1Serial,?g2Serial)))
      And
        # geometry - feature rule
        (?f2[geo:hasDefaultGeometry->?g2]
         ?f1[ogc:asGeomLiteral->?g1Serial]
         ?g2[ogc:asGeomLiteral->?g2Serial]
         External(ogc:function (?g1Serial,?g2Serial)))
      And
        # geometry - geometry rule
        (?f1[ogc:asGeomLiteral->?g1Serial]
         ?f2[ogc:asGeomLiteral->?g2Serial]
         External(ogc:function (?g1Serial,?g2Serial)))
    )
  )
```

NOTE

The GeoSPARQL 1.1 Standard contains a RIF rules artefact expanded for all function generated from this template and Python software for re-issuing the expanded artefact. See [GeoSPARQL Standard structure](#).

11.1. Parameters

- **relation_family**: Specifies the set of topological spatial relations to support.
- **serialization**: Specifies the serialization standard to use for geometry literals.
- **version**: Specifies the version of the serialization format used.

11.2. Simple Features Relation Family (relation_family=Simple Features)

This clause defines requirements for the *Simple Features* relation family. [Table 9](#) specifies the function and property substitutions for each rule in the *Simple Features* relation family.

Req 50 Basic graph pattern matching shall use the semantics defined by the RIF Core Entailment Regime [\[SPARQLENT\]](#) for the RIF rules [\[RIFCORE\]](#) `geor:sfEquals`, `geor:sfDisjoint`, `geor:sfIntersects`, `geor:sfTouches`, `geor:sfCrosses`, `geor:sfWithin`, `geor:sfContains` and `geor:sfOverlaps`.

<http://www.opengis.net/spec/geosparql/1.0/req/query-rewrite-extension/sf-query-rewrite>

Table 9. Simple Features Query Transformation Rules

| Rule | ogc:relation | ogc:function |
|--------------------------------|-------------------------------|--------------------------------|
| <code>geor:sfEquals</code> | <code>geo:sfEquals</code> | <code>geof:sfEquals</code> |
| <code>geor:sfDisjoint</code> | <code>geo:sfDisjoint</code> | <code>geof:sfDisjoint</code> |
| <code>geor:sfIntersects</code> | <code>geo:sfIntersects</code> | <code>geof:sfIntersects</code> |
| <code>geor:sfTouches</code> | <code>geo:sfTouches</code> | <code>geof:sfTouches</code> |
| <code>geor:sfCrosses</code> | <code>geo:sfCrosses</code> | <code>geof:sfCrosses</code> |
| <code>geor:sfWithin</code> | <code>geo:sfWithin</code> | <code>geof:sfWithin</code> |
| <code>geor:sfContains</code> | <code>geo:sfContains</code> | <code>geof:sfContains</code> |
| <code>geor:sfOverlaps</code> | <code>geo:sfOverlaps</code> | <code>geof:sfOverlaps</code> |

11.3. Egenhofer Relation Family (relation_family=Egenhofer)

This clause defines requirements for the *Egenhofer* relation family. [Table 10](#) specifies the function and property substitutions for each rule in the *Egenhofer* relation family.

Req 51 Basic graph pattern matching shall use the semantics defined by the RIF Core Entailment Regime [\[SPARQLENT\]](#) for the RIF rules [\[RIFCORE\]](#) `geor:ehEquals`, `geor:ehDisjoint`, `geor:ehMeet`, `geor:ehOverlap`, `geor:ehCovers`, `geor:ehCoveredBy`, `geor:ehInside` and `geor:ehContains`.

Table 10. Egenhofer Query Transformation Rules

| Rule | ogc:relation | ogc:function |
|------------------|-----------------|------------------|
| geor:ehEquals | geo:ehEquals | geof:ehEquals |
| geor:ehDisjoint | geo:ehDisjoint | geof:ehDisjoint |
| geor:ehMeet | geo:ehMeet | geof:ehMeet |
| geor:ehOverlap | geo:ehOverlap | geof:ehOverlap |
| geor:ehCovers | geo:ehCovers | geof:ehCovers |
| geor:ehCoveredBy | geo:ehCoveredBy | geof:ehCoveredBy |
| geor:ehInside | geo:ehInside | geof:ehInside |
| geor:ehContains | geo:ehContains | geof:ehContains |

11.4. RCC8 Relation Family (relation_family=RCC8)

This clause defines requirements for the *RCC8* relation family. Table 11 specifies the function and property substitutions for each rule in the *RCC8* relation family.

Req 52 Basic graph pattern matching shall use the semantics defined by the RIF Core Entailment Regime [SPARQLENT] for the RIF rules [RIFCORE] geor:rcc8eq, geor:rcc8dc, geor:rcc8ec, geor:rcc8po, geor:rcc8tpi, geor:rcc8tpp, geor:rcc8ntpp and geor:rcc8ntppi.

<http://www.opengis.net/spec/geosparql/1.0/req/query-rewrite-extension/rcc8-query-rewrite>

Table 11. RCC8 Query Transformation Rules

| Rule | ogc:relation | ogc:function |
|----------------|---------------|----------------|
| geor:rcc8eq | geo:rcc8eq | geof:rcc8eq |
| geor:rcc8dc | geo:rcc8dc | geof:rcc8dc |
| geor:rcc8ec | geo:rcc8ec | geof:rcc8ec |
| geor:rcc8po | geo:rcc8po | geof:rcc8po |
| geor:rcc8tpi | geo:rcc8tpi | geof:rcc8tpi |
| geor:rcc8tpp | geo:rcc8tpp | geof:rcc8tpp |
| geor:rcc8ntpp | geo:rcc8ntpp | geof:rcc8ntpp |
| geor:rcc8ntppi | geo:rcc8ntppi | geof:rcc8ntppi |

11.5. Special Considerations

The applicability of GeoSPARQL rules in certain circumstances has intentionally been left undefined.

The first situation arises for triple patterns with unbound predicates. Consider the query pattern below:

```
{ my:feature1 ?p my:feature2 }
```

When using a query transformation strategy, this triple pattern could invoke none of the GeoSPARQL rules or all of the rules. Implementations are free to support either of these alternatives.

The second situation arises when supporting GeoSPARQL rules in the presence of RDFS Entailment. The existence of a topological relation (possibly derived from a GeoSPARQL rule) can entail other RDF triples. For example, if `geo:sfOverlaps` has been defined as an `rdfs:subPropertyOf` the property `my:overlaps`, and the RDF triple `my:feature1 geo:sfOverlaps my:feature2` has been derived from a GeoSPARQL rule, then the RDF triple `my:feature1 my:overlaps my:feature2` can be entailed. Implementations may support such entailments but are not required to.

12. Future Work

Many future extensions of this standard are possible and, since the release of GeoSPARQL 1.0, many extensions have been made.

The GeoSPARQL 1.1 release incorporates many additions requested of the GeoSPARQL 1.0 Standard, including the use of new serializations. Where GeoSPARQL 1.0 supported GML & WKT, GeoSPARQL 1.1 also supports GeoJSON, KML and a generic DGGs literal. GeoSPARQL 1.1 also supports spatial scalar measurements.

Plans for future GeoSPARQL releases have been mooted but won't be articulated here, instead they will be discussed and decided upon by the OGC GeoSPARQL Standards Working Group and related groups. Readers of this document are encouraged to seek out those groups' lists of issues and standards change requests rather than looking for ideas here that will surely age badly.

Annex A - Abstract Test Suite (normative)

A.0 Overview

This Annex lists tests for the Conformance Classes defined in the main body sections of this Specification with links to their Requirements and test purpose method and type.

A.1 Conformance Class: Core

Conformance Class IRI: [/conf/core](#)

A.1.1 SPARQL

A.1.1.1 [/conf/core/sparql-protocol](#)

Requirement: [/req/core/sparql-protocol](#)

Implementations shall support the SPARQL Query Language for RDF [\[SPARQL\]](#), the SPARQL Protocol for RDF [\[SPARQLPROT\]](#) and the SPARQL Query Results XML Format [\[SPARQLRESX\]](#).

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that the implementation accepts SPARQL queries and returns the correct results in the correct format, according to the SPARQL Query Language for RDF, the SPARQL Protocol for RDF and SPARQL Query Results XML Format W3C specifications.
- c. **Reference:** [Section 4.1.4](#)
- d. **Test Type:** Capabilities

A.1.2 RDF Classes & Properties

A.1.2.1 [/conf/core/spatial-object-class](#)

Requirement: [/req/core/spatial-object-class](#)

Implementations shall allow the RDFS class [geo:SpatialObject](#) to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving [geo:SpatialObject](#) return the correct result on a test dataset.
- c. **Reference:** [Section 6.2.1](#)
- d. **Test Type:** Capabilities

A.1.2.2 [/conf/core/feature-class](#)

Requirement: [/req/core/feature-class](#) Implementations shall allow the RDFS class [geo:Feature](#) to be used in SPARQL graph patterns.

- a. **Test purpose:** check conformance with this requirement
- b. **Test method:** verify that queries involving [geo:Feature](#) return the correct result on a test dataset.
- c. **Reference:** [Section 6.2.2](#)
- d. **Test Type:** Capabilities

A.1.2.3 /conf/core/spatial-object-collection-class

Requirement: /req/core/spatial-object-collection-class

Implementations shall allow the RDFS class `geo:SpatialObjectCollection` to be used in SPARQL graph patterns.

- a. **Test purpose:** check conformance with this requirement
- b. **Test method:** verify that queries involving `geo:SpatialObjectCollection` return the correct result on a test dataset.
- c. **Reference:** [Section 6.2.3](#)
- d. **Test Type:** Capabilities

A.1.2.4 /conf/core/feature-collection-class

Requirement: /req/core/feature-collection-class

Implementations shall allow the RDFS class `geo:FeatureCollection` to be used in SPARQL graph patterns.

- a. **Test purpose:** check conformance with this requirement
- b. **Test method:** verify that queries involving `geo:FeatureCollection` return the correct result on a test dataset.
- c. **Reference:** [Section 6.2.4](#)
- d. **Test Type:** Capabilities

A.1.2.5 /conf/core/spatial-object-properties

Implementations shall allow the properties `geo:hasSize`, `geo:hasMetricSize`, `geo:hasLength`, `geo:hasMetricLength`, `geo:hasPerimeterLength`, `geo:hasMetricPerimeterLength`, `geo:hasArea`, `geo:hasMetricArea`, `geo:hasVolume` and `geo:hasMetricVolume`. to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving these properties return the correct result for a test dataset.
- c. **Reference:** [Section 6.3](#)
- d. **Test Type:** Capabilities

A.2 Conformance Class: Topology Vocabulary Extension (relation_family)

Conformance Class IRI: [/conf/topology-vocab-extension](#)

A.2.1 relation_family = Simple Features

A.2.1.1 [/conf/topology-vocab-extension/sf-spatial-relations](#)

Requirement: [/req/topology-vocab-extension/sf-spatial-relations](#)

Implementations shall allow the properties [geo:sfEquals](#), [geo:sfDisjoint](#), [geo:sfIntersects](#), [geo:sfTouches](#), [geo:sfCrosses](#), [geo:sfWithin](#), [geo:sfContains](#) and [geo:sfOverlaps](#) to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving these properties return the correct result for a test dataset.
- c. **Reference:** [Section 7.2](#)
- d. **Test Type:** Capabilities

A.2.2 relation_family = Egenhofer

A.2.2.1 [/conf/topology-vocab-extension/eh-spatial-relations](#)

Requirement: [/req/topology-vocab-extension/eh-spatial-relations](#)

Implementations shall allow the properties [geo:ehEquals](#), [geo:ehDisjoint](#), [geo:ehMeet](#), [geo:ehOverlap](#), [geo:ehCovers](#), [geo:ehCoveredBy](#), [geo:ehInside](#) and [geo:ehContains](#) to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving these properties return the correct result for a test dataset.
- c. **Reference:** [Section 7.3](#)
- d. **Test Type:** Capabilities

A.2.3 relation_family = RCC8

A.2.3.1 [/conf/topology-vocab-extension/rcc8-spatial-relations](#)

Requirement: [/req/topology-vocab-extension/rcc8-spatial-relations](#)

Implementations shall allow the properties [geo:rcc8eq](#), [geo:rcc8dc](#), [geo:rcc8ec](#), [geo:rcc8po](#),

`geo:rcc8tppi`, `geo:rcc8tpp`, `geo:rcc8ntpp`, `geo:rcc8ntppi` to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving these properties return the correct result for a test dataset.
- c. **Reference:** [Section 7.4](#)
- d. **Test Type:** Capabilities

A.3 Conformance Class: Geometry Extension (serialization, version)

Conformance Class IRI: [/conf/geometry-extension](#)

A.3.1 Tests for all Serializations

A.3.1.1 [/conf/geometry-extension/geometry-class](#)

Requirement: [/req/geometry-extension/geometry-class](#)

Implementations shall allow the RDFS class [geo:Geometry](#) to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving [geo:Geometry](#) return the correct result on a test dataset
- c. **Reference:** [Section 8.2.1](#)
- d. **Test Type:** Capabilities

A.3.1.6 [/conf/geometry-extension/geometry-collection-class](#)

Requirement: [/req/geometry-extension/geometry-collection-class](#)

Implementations shall allow the RDFS class [Geometry Collection](#) to be used in SPARQL graph patterns.

- a. **Test purpose:** check conformance with this requirement
- b. **Test method:** verify that queries involving [Geometry Collection](#) return the correct result on a test dataset
- c. **Reference:** [Section 8.2.2](#)
- d. **Test Type:** Capabilities

A.3.1.2 [/conf/geometry-extension/feature-properties](#)

Requirement: [/req/geometry-extension/feature-properties](#)

Implementations shall allow the properties [geo:hasGeometry](#), [geo:hasDefaultGeometry](#), [geo:hasLength](#), [geo:hasArea](#), [geo:hasVolume](#), [geo:hasCentroid](#), [geo:hasBoundingBox](#) and [geo:hasSpatialResolution](#) to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving these properties return the correct result for a test dataset.
- c. **Reference:** [Section 6.4](#)

- d. **Test Type:** Capabilities

A.3.1.3 /conf/geometry-extension/geometry-properties

Requirement: /req/geometry-extension/geometry-properties

Implementations shall allow the properties `geo:dimension`, `geo:coordinateDimension`, `geo:spatialDimension`, `geo:isEmpty`, `geo:isSimple` and `geo:hasSerialization` to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving these properties return the correct result for a test dataset.
- c. **Reference:** [Section 8.3](#)
- d. **Test Type:** Capabilities

A.3.1.4 /conf/geometry-extension/query-functions

Requirement: /req/geometry-extension/query-functions

Implementations shall support the functions `geof:distance`, `geof:buffer`, `geof:intersection`, `geof:union`, `geof:isEmpty`, `geof:isSimple`, `geof:area`, `geof:length`, `geof:numGeometries`, `geof:geometryN`, `geof:transform`, `geof:dimension`, `geof:difference`, `geof:symDifference`, `geof:envelope` and `geof:boundary` as SPARQL extension functions, consistent with the definitions of their corresponding functions in Simple Features [\[ISO19125-1\]](#) (`distance`, `buffer`, `intersection`, `union`, `isEmpty`, `isSimple`, `area`, `length`, `numGeometries`, `geometryN`, `transform`, `dimension`, `difference`, `symDifference`, `envelope` and `boundary` respectively) and other attached definitions and also `geof:maxX`, `geof:maxY`, `geof:maxZ`, `geof:minX`, `geof:minY` and `geof:minZ` SPARQL extension functions.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving each of the following functions returns the correct result for a test dataset when using the specified serialization and version: `geof:distance`, `geof:buffer`, `geof:intersection`, `geof:union`, `geof:isEmpty`, `geof:isSimple`, `geof:area`, `geof:length`, `geof:numGeometries`, `geof:geometryN`, `geof:transform`, `geof:dimension`, `geof:difference`, `geof:symDifference`, `geof:envelope` and `geof:boundary`.
- c. **Reference:** [Section 8.5](#)
- d. **Test Type:** Capabilities

A.3.1.5 /conf/geometry-extension/srid-function

Requirement: /req/geometry-extension/srid-function

Implementations shall support `get SRID` as a SPARQL extension function.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a SPARQL query involving the `get SRID` function returns the correct result for a test dataset when using the specified serialization and version.

c. **Reference:** [Section 8.5.24](#)

d. **Test Type:** Capabilities

A.3.1.5 /conf/geometry-extension/sa-functions

Requirement: /req/geometry-extension/sa-functions

Implementations shall support `geof:boundingBox`, `geof:boundingCircle`, `geof:centroid`, `geof:concatLines`, `geof:concaveHull`, `geof:convexHull` and `geof:union2` as a SPARQL extension functions.

a. **Test purpose:** Check conformance with this requirement

b. **Test method:** Verify that queries involving these functions return the correct result for a test dataset.

c. **Reference:** [\[function_safuncs\]](#)

d. **Test Type:** Capabilities

A.3.2 serialization = WKT

A.3.2.1 /conf/geometry-extension/wkt-literal

Requirement: /req/geometry-extension/wkt-literal

All RDFS Literals of type `geo:wktLiteral` shall consist of an optional IRI identifying the coordinate reference system and a required Well Known Text (WKT) description of a geometric value. Valid `geo:wktLiteral` instances are formed by either a WKT string as defined in [\[ISO13249\]](#) or by concatenating a valid absolute IRI, as defined in [\[IETF3987\]](#), enclose in angled brackets (`<` & `>`) followed by a single space (Unicode U+0020 character) as a separator, and a WKT string as defined in [\[ISO13249\]](#).

a. **Test purpose:** Check conformance with this requirement

b. **Test method:** Verify that queries involving [WKT Literal](#) values return the correct result for a test dataset.

c. **Reference:** [Section 8.4.1.1](#)

d. **Test Type:** Capabilities

A.3.2.2 /conf/geometry-extension/wkt-literal-default-srs

Requirement: /req/geometry-extension/wkt-literal-default-srs

The IRI `<http://www.opengis.net/def/crs/OGC/1.3/CRS84>` shall be assumed as the spatial reference system for `geo:wktLiteral` instances that do not specify an explicit spatial reference system IRI.

a. **Test purpose:** Check conformance with this requirement

b. **Test method:** Verify that queries involving [WKT Literal](#) values without an explicit encoded SRS IRI return the correct result for a test dataset.

c. **Reference:** [Section 8.4.1.1](#)

d. **Test Type:** Capabilities

A.3.2.3 `/conf/geometry-extension/wkt-axis-order`

Requirement: `/req/geometry-extension/wkt-axis-order`

Coordinate tuples within [WKT Literal](#) instances shall be interpreted using the axis order defined in the SRS used.

a. **Test purpose:** Check conformance with this requirement

b. **Test method:** Verify that queries involving [WKT Literal](#) values return the correct result for a test dataset.

c. **Reference:** [Section 8.4.1.1](#)

d. **Test Type:** Capabilities

A.3.2.4 `/conf/geometry-extension/wkt-literal-empty`

Requirement: `/req/geometry-extension/wkt-literal-empty`

An empty RDFS Literal of type [WKT Literal](#) shall be interpreted as an empty geometry.

a. **Test purpose:** Check conformance with this requirement

b. **Test method:** Verify that queries involving empty [WKT Literal](#) values return the correct result for a test dataset.

c. **Reference:** [Section 8.4.1.1](#)

d. **Test Type:** Capabilities

A.3.2.5 `/conf/geometry-extension/geometry-as-wkt-literal`

Requirement: `/req/geometry-extension/geometry-as-wkt-literal`

Implementations shall allow the RDF property `geo:asWKT` to be used in SPARQL graph patterns.

a. **Test purpose:** Check conformance with this requirement

b. **Test method:** Verify that queries involving the `geo:asWKT` property return the correct result for a test dataset.

c. **Reference:** [Section 8.4.1.2](#)

d. **Test Type:** Capabilities

A.3.2.6 `/req/geometry-extension/asWKT-function`

Requirement: `/req/geometry-extension/asWKT-function`

Implementations shall support `geof:asWKT`, as a SPARQL extension function

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving the `geof:asWKT` function returns the correct result for a test dataset when using the specified serialization and version.
- c. **Reference:** [\[function_aswkt\]](#)
- d. **Test Type:** Capabilities

A.3.3 serialization = GML

A.3.3.1 `/conf/geometry-extension/gml-literal`

Requirement: `/req/geometry-extension/gml-literal`

All `geo:gmlLiteral` instances shall consist of a valid element from the GML schema that implements a subtype of `GM_Object` as defined in [OGC 07-036].

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving `geo:gmlLiteral` values return the correct result for a test dataset.
- c. **Reference:** [Section 8.4.2.1](#)
- d. **Test Type:** Capabilities

A.3.3.2 `/conf/geometry-extension/gml-literal-empty`

Requirement: `/req/geometry-extension/gml-literal-empty`

An empty `geo:gmlLiteral` shall be interpreted as an empty geometry.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving empty `geo:gmlLiteral` values return the correct result for a test dataset.
- c. **Reference:** [Section 8.4.2.1](#)
- d. **Test Type:** Capabilities

A.3.3.3 `/conf/geometry-extension/gml-profile`

Requirement: `/req/geometry-extension/gml-profile`

Implementations shall document supported GML profiles.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Examine the implementation's documentation to verify that the supported GML profiles are documented.
- c. **Reference:** [Section 8.4.2.1](#)
- d. **Test Type:** Documentation

A.3.3.4 /conf/geometry-extension/geometry-as-gml-literal

Requirement: /req/geometry-extension/geometry-as-gml-literal

Implementations shall allow the RDF property `geo:asGML` to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving the `geo:asGML` property return the correct result for a test dataset.
- c. **Reference:** [Section 8.4.2.2](#)
- d. **Test Type:** Capabilities

A.3.3.5 /req/geometry-extension/asGML-function

Requirement: /req/geometry-extension/asGML-function

Implementations shall support `geof:asGML`, as a SPARQL extension function

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving the `geof:asGML` function returns the correct result for a test dataset when using the specified serialization and version.
- c. **Reference:** [\[function_asgml\]](#)
- d. **Test Type:** Capabilities

A.3.4 serialization = GEOJSON

A.3.4.1 /req/geometry-extension/geojson-literal

Requirement: /req/geometry-extension/geojson-literal

All `geo:geoJSONLiteral` instances shall consist of valid JSON that conforms to the GeoJSON specification [\[GEOJSON\]](#)

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving `geo:geoJSONLiteral` values return the correct result for a test dataset.
- c. **Reference:** [Section 8.4.2.2](#)
- d. **Test Type:** Capabilities

A.3.4.2 /req/geometry-extension/geojson-literal-srs

Requirement: /req/geometry-extension/geojson-literal-default-srs

The IRI [<http://www.opengis.net/def/crs/OGC/1.3/CRS84>](http://www.opengis.net/def/crs/OGC/1.3/CRS84) shall be assumed as the SRS for `geo:geoJSONLiteral` instances that do not specify an explicit SRS IRI.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving `geo:geoJSONLiteral` values without an explicit encoded SRS IRI return the correct result for a test dataset.
- c. **Reference:** [Section 8.4.3.1](#)
- d. **Test Type:** Capabilities

A.3.4.3 `/req/geometry-extension/geojson-literal-empty`

Requirement: `/req/geometry-extension/geojson-literal-empty`

An empty `geo:geoJSONLiteral` shall be interpreted as an empty geometry.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving empty `geo:geoJSONLiteral` values return the correct result for a test dataset.
- c. **Reference:** [Section 8.4.3.1](#)
- d. **Test Type:** Capabilities

A.3.4.4 `/req/geometry-extension/geometry-as-geojson-literal`

Requirement: `/req/geometry-extension/geometry-as-geojson-literal`

Implementations shall allow the RDF property `geo:asGeoJSON` to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving the `geo:asGeoJSON` property return the correct result for a test dataset.
- c. **Reference:** [Section 8.4.3.2](#)
- d. **Test Type:** Capabilities

A.3.4.5 `/req/geometry-extension/asGeoJSON-function`

Requirement: `/req/geometry-extension/asGeoJSON-function`

Implementations shall support `geof:asGeoJSON`, as a SPARQL extension function

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving the `geof:asGeoJSON` function returns the correct result for a test dataset when using the specified serialization and version.
- c. **Reference:** [\[function_asgeojson\]](#)
- d. **Test Type:** Capabilities

A.3.5 serialization = KML

A.3.5.1 /req/geometry-extension/kml-literal

Requirement: /req/geometry-extension/kml-literal

All `geo:kmlLiteral` instances shall consist of a valid element from the KML schema that implements a `kml:AbstractObjectGroup` as defined in [OGCKML].

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving `geo:kmlLiteral` values return the correct result for a test dataset.
- c. **Reference:** [`rdfs_datatype_geomkmlliteral`]
- d. **Test Type:** Capabilities

A.3.5.2 /req/geometry-extension/kml-literal-srs

Requirement: /req/geometry-extension/kml-literal-default-srs

The IRI `<http://www.opengis.net/def/crs/OGC/1.3/CRS84>` shall be assumed as the SRS for `geo:kmlLiteral` instances that do not specify an explicit SRS IRI.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving `geo:kmlLiteral` values without an explicit encoded SRS IRI return the correct result for a test dataset.
- c. **Reference:** [`rdfs_datatype_geomkmlliteral`]
- d. **Test Type:** Capabilities

A.3.5.3 /req/geometry-extension/kml-literal-empty

Requirement: /req/geometry-extension/kml-literal-empty

An empty `geo:kmlLiteral` shall be interpreted as an empty geometry.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving empty `geo:kmlLiteral` values return the correct result for a test dataset.
- c. **Reference:** [`rdfs_datatype_geomkmlliteral`]
- d. **Test Type:** Capabilities

A.3.5.4 /req/geometry-extension/geometry-as-kml-literal

Requirement: /req/geometry-extension/geometry-as-kml-literal

Implementations shall allow the RDF property `geo:asKML` to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving the `geo:asKML` property return the correct result for a test dataset.
- c. **Reference:** [Section 8.4.4.2](#)
- d. **Test Type:** Capabilities

A.3.5.5 `/req/geometry-extension/asKML-function`

Requirement: `/req/geometry-extension/asKML-function`

Implementations shall support `as KML`, as a SPARQL extension function

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving the `geof:asKML` function returns the correct result for a test dataset when using the specified serialization and version.
- c. **Reference:** [\[function_askml\]](#)
- d. **Test Type:** Capabilities

A.3.6 serialization = DGGS

A.3.6.1 `/req/geometry-extension/dggs-literal`

Requirement: `/req/geometry-extension/dggs-literal`

All RDFS Literals of type `geo:dggsLiteral` shall consist of a DGGS geometry serialization formulated according to a specific DGGS literal type identified by a datatype specializing this generic datatype.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries do not use use this datatype but instead use specializations of it.
- c. **Reference:** [\[dggs_serialization_serializationdggs\]](#)
- d. **Test Type:** Capabilities

A.3.6.2 `/req/geometry-extension/dggs-literal-empty`

Requirement: `/req/geometry-extension/dggs-literal-empty`

An empty `geo:dggsLiteral` shall be interpreted as an empty geometry.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving empty `geo:dggsLiteral` values return the correct result for a test dataset.
- c. **Reference:** [\[dggs_serialization_serializationdggs\]](#)
- d. **Test Type:** Capabilities

A.3.6.3 /req/geometry-extension/geometry-as-dggs-literal

Requirement: /req/geometry-extension/geometry-as-dggs-literal

Implementations shall allow the RDF property `geo:asDGGS` to be used in SPARQL graph patterns.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving the `geo:asDGGS` property return the correct result for a test dataset.
- c. **Reference:** [Section 8.4.5.2](#)
- d. **Test Type:** Capabilities

A.3.6.4 /req/geometry-extension/asDGGS-function

Requirement: /req/geometry-extension/asDGGS-function

Implementations shall support `geof:asDGGS`, as a SPARQL extension function

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving the `geof:asDGGS` function returns the correct result for a test dataset when using the specified serialization and version.
- c. **Reference:** [\[function_asdggs\]](#)
- d. **Test Type:** Capabilities

A.4 Conformance Class: Geometry Topology Extension (relation_family, serialization, version)

Conformance Class IRI: </conf/geometry-topology-extension>

A.4.1 Tests for all relation families

A.4.1.1 </conf/geometry-topology-extension/relate-query-function>

Requirement: </req/geometry-topology-extension/relate-query-function>

Implementations shall support `geof:relate` as a SPARQL extension function, consistent with the relate operator defined in Simple Features [\[ISO19125-1\]](#).

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving the `geof:relate` function returns the correct result for a test dataset when using the specified serialization and version.
- c. **Reference:** [Section 9.2](#)
- d. **Test Type:** Capabilities

A.4.2 relation_family = Simple Features

A.4.2.1 </conf/geometry-topology-extension/sf-query-functions>

Requirement: </req/geometry-topology-extension/sf-query-functions>

Implementations shall support `geof:sfEquals`, `geof:sfDisjoint`, `geof:sfIntersects`, `geof:sfTouches`, `geof:sfCrosses`, `geof:sfWithin`, `geof:sfContains` and `geof:sfOverlaps` as SPARQL extension functions, consistent with their corresponding DE-9IM intersection patterns, as defined by Simple Features [\[ISO19125-1\]](#).

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving each of the following functions returns the correct result for a test dataset when using the specified serialization and version: `geof:sfEquals`, `geof:sfDisjoint`, `geof:sfIntersects`, `geof:sfTouches`, `geof:sfCrosses`, `geof:sfWithin`, `geof:sfContains`, `geof:sfOverlaps`.
- c. **Reference:** [Section 7.2](#)
- d. **Test Type:** Capabilities

A.4.3 relation_family = Egenhofer

A.4.3.1 /conf/geometry-topology-extension/eh-query-functions

Requirement: /req/geometry-topology-extension/eh-query-functions

Implementations shall support `geof:ehEquals`, `geof:ehDisjoint`, `geof:ehMeet`, `geof:ehOverlap`, `geof:ehCovers`, `geof:ehCoveredBy`, `geof:ehInside` and `geof:ehContains` as SPARQL extension functions, consistent with their corresponding DE-9IM intersection patterns, as defined by Simple Features [ISO19125-1].

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving each of the following functions returns the correct result for a test dataset when using the specified serialization and version:
`geof:ehEquals`, `geof:ehDisjoint`, `geof:ehMeet`, `geof:ehOverlap`, `geof:ehCovers`, `geof:ehCoveredBy`, `geof:ehInside`, `geof:ehContains`.
- c. **Reference:** [Section 7.3](#)
- d. **Test Type:** Capabilities

A.4.4 relation_family = RCC8

A.4.4.1 /conf/geometry-topology-extension/rcc8-query-functions

Requirement: /req/geometry-topology-extension/rcc8-query-functions

Implementations shall support `geof:rcc8eq`, `geof:rcc8dc`, `geof:rcc8ec`, `geof:rcc8po`, `geof:rcc8tppi`, `geof:rcc8tpp`, `geof:rcc8ntpp` and `geof:rcc8ntppi` as SPARQL extension functions, consistent with their corresponding DE-9IM intersection patterns, as defined by Simple Features [ISO19125-1].

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving each of the following functions returns the correct result for a test dataset when using the specified serialization and version:
`geof:rcc8eq`, `geof:rcc8dc`, `geof:rcc8ec`, `geof:rcc8po`, `geof:rcc8tppi`, `geof:rcc8tpp`, `geof:rcc8ntpp`, `geof:rcc8ntppi`.
- c. **Reference:** [Section 7.4](#)
- d. **Test Type:** Capabilities

A.5 Conformance Class: RDFS Entailment Extension (relation_family, serialization, version)

Conformance Class IRI: [/conf/rdfs-entailment-extension](#)

A.5.1 Tests for all implementations

A.5.1.1 [/conf/rdfs-entailment-extension/bgp-rdfs-ent](#)

Requirement: [/req/rdfs-entailment-extension/bgp-rdfs-ent](#)

Basic graph pattern matching shall use the semantics defined by the RDFS Entailment Regime [\[SPARQLENT\]](#).

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving entailed RDF triples returns the correct result for a test dataset using the specified serialization, version and relation_family.
- c. **Reference:** [Section 10.2](#)
- d. **Test Type:** Capabilities

A.5.2 serialization = WKT

A.5.2.1 [/conf/rdfs-entailment-extension/wkt-geometry-types](#)

Requirement: [/req/rdfs-entailment-extension/wkt-geometry-types](#)

Implementations shall support graph patterns involving terms from an RDFS/OWL class hierarchy of geometry types consistent with the one in the specified version of Simple Features [\[ISO19125-1\]](#).

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving WKT Geometry types returns the correct result for a test dataset using the specified version of Simple Features.
- c. **Reference:** [Section 10.3.1](#)
- d. **Test Type:** Capabilities

A.5.3 serialization = GML

A.5.3.1 [/conf/rdfs-entailment-extension/gml-geometry-types](#)

Requirement: [/req/rdfs-entailment-extension/gml-geometry-types](#)

Implementations shall support graph patterns involving terms from an RDFS/OWL class hierarchy

of geometry types consistent with the GML schema that implements GM_Object using the specified version of GML [\[OGC07-036\]](#).

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that a set of SPARQL queries involving GML Geometry types returns the correct result for a test dataset using the specified version of GML.
- c. **Reference:** [Section 10.4.1](#)
- d. **Test Type:** Capabilities

A.6 Conformance Class: Query Rewrite Extension (relation_family, serialization, version)

Conformance Class IRI: </conf/query-rewrite-extension>

A.6.1 relation_family = Simple Features

A.6.1.1 </conf/query-rewrite-extension/sf-query-rewrite>

Requirement: </req/query-rewrite-extension/sf-query-rewrite>

Basic graph pattern matching shall use the semantics defined by the RIF Core Entailment Regime [\[SPARQLENT\]](#) for the RIF rules [\[RIFCORE\]](#) [geor:sfEquals](#), [geor:sfDisjoint](#), [geor:sfIntersects](#), [geor:sfTouches](#), [geor:sfCrosses](#), [geor:sfWithin](#), [geor:sfContains](#) and [geor:sfOverlaps](#).

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving the following query transformation rules return the correct result for a test dataset when using the specified serialization and version:
[geor:sfEquals](#), [geor:sfDisjoint](#), [geor:sfIntersects](#), [geor:sfTouches](#), [geor:sfCrosses](#), [geor:sfWithin](#), [geor:sfContains](#) and [geor:sfOverlaps](#).
- c. **Reference:** [Section 9.3](#)
- d. **Test Type:** Capabilities

A.6.2 relation_family = Egenhofer

A.6.2.1 </conf/query-rewrite-extension/eh-query-rewrite>

Requirement: </req/query-rewrite-extension/eh-query-rewrite>

Basic graph pattern matching shall use the semantics defined by the RIF Core Entailment Regime [\[SPARQLENT\]](#) for the RIF rules [\[RIFCORE\]](#) [geor:ehEquals](#), [geor:ehDisjoint](#), [geor:ehMeet](#), [geor:ehOverlap](#), [geor:ehCovers](#), [geor:ehCoveredBy](#), [geor:ehInside](#) and [geor:ehContains](#).

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving the following query transformation rules return the correct result for a test dataset when using the specified serialization and version:
[geor:ehEquals](#), [geor:ehDisjoint](#), [geor:ehMeet](#), [geor:ehOverlap](#), [geor:ehCovers](#), [geor:ehCoveredBy](#), [geor:ehInside](#), [geor:ehContains](#).
- c. **Reference:** [Section 9.4](#)
- d. **Test Type:** Capabilities

A.6.3 relation_family = RCC8

A.6.3.1 /conf/query-rewrite-extension/rcc8-query-rewrite

Requirement: /req/query-rewrite-extension/rcc8-query-rewrite

Basic graph pattern matching shall use the semantics defined by the RIF Core Entailment Regime [SPARQLENT] for the RIF rules [RIFCORE] `geor:rcc8eq`, `geor:rcc8dc`, `geor:rcc8ec`, `geor:rcc8po`, `geor:rcc8tppi`, `geor:rcc8tpp`, `geor:rcc8ntpp` and `geor:rcc8ntppi`.

- a. **Test purpose:** Check conformance with this requirement
- b. **Test method:** Verify that queries involving the following query transformation rules return the correct result for a test dataset when using the specified serialization and version: `geor:rcc8eq`, `geor:rcc8dc`, `geor:rcc8ec`, `geor:rcc8po`, `geor:rcc8tppi`, `geor:rcc8tpp`, `geor:rcc8ntpp`, `geor:rcc8ntppi`.
- c. **Reference:** [Section 11.4](#)
- d. **Test Type:** Capabilities

Annex B - Functions Summary (normative)

B.0 Overview

This annex summarises all the functions defined in GeoSPARQL, providing descriptions of their parameter requirements and return types.

B.1 Functions Summary Table

| Function Name | Input Parameters | Valid Input Types | Output Datatype | Output Datatype Subtypes | 2D | 3D | Comment |
|----------------------------------|-----------------------|---|-----------------|--------------------------|-----|-----|---------|
| Simple Features Functions | | | | | | | |
| geof:sfContains | 2x ogc:geomLiteral | 1x Polygon(GeoJSON,WKT,GML,KML), 1x Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:sfCrosses | 2x ogc:geomLiteral | 2x LineString(GeoJSON,WKT,GML,KML) | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:sfDisjoint | 2x ogc:geomLiteral | 2x Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:sfEquals | 2x ogc:geomLiteral | 2x Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:sfIntersects | 2x ogc:geomLiteral | 2x Polygon(GeoJSON,WKT,GML,KML) | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:sfOverlaps | 2x ogc:geomLiteral | 2x Polygon(GeoJSON,WKT,GML,KML) | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:sfTouches | 2x ogc:geomLiteral | 2x Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:sfWithin | 2x ogc:geomLiteral | 1x Geometry, 1x Polygon(GeoJSON,WKT,GML,KML) | xsd:boolean | true,false,1,0 | Yes | Yes | |

| Function Name | Input Parameters | Valid Input Types | Output Datatype | Output Datatype Subtypes | 2D | 3D | Comment |
|---|-----------------------|----------------------------|-----------------|--------------------------|-----|-----|---------|
| Egenhofer Functions | | | | | | | |
| geof:ehContains | 2x ogc:geomLiteral | 1x Polygon, 1x Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:ehCoveredBy | 2x ogc:geomLiteral | 1x Polygon, 1x Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:ehCovers | 2x ogc:geomLiteral | 1x Polygon, 1x Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:ehDisjoint | 2x ogc:geomLiteral | 2x Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:ehEquals | 2x ogc:geomLiteral | 2x Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:ehMeet | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:ehOverlap | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:ehInside | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| Region Connection Calculus Functions | | | | | | | |
| geof:rcc8dc | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:rcc8ec | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:rcc8eq | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:rcc8ntpp | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |

| Function Name | Input Parameters | Valid Input Types | Output Datatype | Output Datatype Subtypes | 2D | 3D | Comment |
|------------------------------------|------------------------------|-------------------|-----------------|--|-----|-----|---------|
| geof:rcc8ntppi | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:rcc8po | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:rcc8tp | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:rcc8tpi | 2x ogc:geomLiteral | | xsd:boolean | true,false,1,0 | Yes | Yes | |
| Spatial Aggregate Functions | | | | | | | |
| geof:aggBoundingBox | 1 or more ogc:geomLiteral | | ogc:geomLiteral | square Polygon(GeoJSON,WKT,GML,KML), CellList(DGGS) | Yes | Yes | |
| geof:aggBoundingCircle | 1 or more ogc:geomLiteral | | ogc:geomLiteral | Polygon(GeoJSON,WKT,GML,KML) CellList(DGGS) | Yes | Yes | |
| geof:aggCentroid | 1 or more ogc:geomLiteral | | ogc:geomLiteral | Point(GeoJSON,WKT,GML,KML Cell(DGGS) | Yes | Yes | |
| geof:aggConcatLines | 1 or more ogc:geomLiteral | | ogc:geomLiteral | square LineString(GeoJSON,WKT,GML,KML OrderedCellList(DGGS) | Yes | Yes | |

| Function Name | Input Parameters | Valid Input Types | Output Datatype | Output Datatype Subtypes | 2D | 3D | Comment |
|--|--|------------------------------|-----------------|---|-----|-----|---------|
| geof:aggConcaveHull | 1 or more ogc:geomLiteral | | ogc:geomLiteral | Polygon(GeoJSON,WKT,GML,KML CellList(DGS)) | Yes | Yes | |
| geof:aggConvexHull | 1 or more ogc:geomLiteral | | ogc:geomLiteral | Polygon(GeoJSON,WKT,GML,KML CellList(DGS)) | Yes | Yes | |
| geof:aggUnion | 1 or more ogc:geomLiteral | | ogc:geomLiteral | Polygon(GeoJSON,WKT,GML,KML CellList(DGS)) | Yes | Yes | |
| Non-topological query functions | | | | | | | |
| geof:area | 1x ogc:geomLiteral | Polygon(GeoJSON,WKT,GML,KML) | xsd:double | xsd:double | Yes | No | |
| geof:boundary | 1x ogc:geomLiteral | Polygon(GeoJSON,WKT,GML,KML) | ogc:geomLiteral | LineString(GeoJSON,WKT,GML,KML) | Yes | Yes | |
| geof:buffer | 1x ogc:geomLiteral, 1x xsd:double, 1x xsd:anyURI | Geometry | ogc:geomLiteral | (Multi)Polygon(GeoJSON,WKT,GML,KML) | Yes | Yes | |
| geof:dimension | 1x ogc:geomLiteral | Geometry | xsd:double | xsd:double | Yes | Yes | |
| geof:difference | 2x ogc:geomLiteral | | ogc:geomLiteral | (Multi)Polygon(GeoJSON,WKT,GML,KML) | Yes | Yes | |

| Function Name | Input Parameters | Valid Input Types | Output Datatype | Output Datatype Subtypes | 2D | 3D | Comment |
|--------------------|---|---|-------------------------------------|-------------------------------------|-----|-----|---------|
| geof:distance | 2x ogc:geomLiteral, 1x xsd:anyURI | Geometry | xsd:double | xsd:double | Yes | Yes | |
| geof:envelope | 1x ogc:geomLiteral, 1x xsd:anyURI | | ogc:geomLiteral | (Multi)Polygon(GeoJSON,WKT,GML,KML) | Yes | Yes | |
| geof:geometryN | 1x ogc:geomLiteral | GeometryCollection(GeoJSON,WKT,GML,KML) | xsd:double | xsd:double | Yes | No | |
| geof:intersection | 2x ogc:geomLiteral | 2x Geometry | ogc:geomLiteral | Polygon(GeoJSON,WKT,GML,KML) | Yes | Yes | |
| geof:isEmpty | 1x ogc:geomLiteral | Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:isSimple | 1x ogc:geomLiteral | Geometry | xsd:boolean | true,false,1,0 | Yes | Yes | |
| geof:length | 1x ogc:geomLiteral | Polygon(GeoJSON,WKT,GML,KML) | xsd:double | xsd:double | Yes | No | |
| geof:numGeometries | 1x ogc:geomLiteral | Geometry(GeoJSON,WKT,GML,KML) | xsd:double | xsd:double | Yes | No | |
| geof:symDifference | 2x ogc:geomLiteral | 2x Geometry | (Multi)Polygon(GeoJSON,WKT,GML,KML) | Yes | Yes | | |
| geof:transform | 1x ogc:geomLiteral, 1x xsd:anyURI | Geometry(GeoJSON,WKT,GML,KML) | ogc:geomLiteral | Geometry | Yes | No | |

| Function Name | Input Parameters | Valid Input Types | Output Datatype | Output Datatype Subtypes | 2D | 3D | Comment |
|--------------------------------|---|-------------------|--------------------|------------------------------|-----|-----|---------|
| geof:union | 2x ogc:geomLiteral | 2x Geometry | ogc:geomLiteral | Polygon(GeoJSON,WKT,GML,KML) | Yes | Yes | |
| Serialization functions | | | | | | | |
| geof:asDGS | 1x ogc:geomLiteral | Geometry | geo:dggsLiteral | geo:dggsLiteral | Yes | Yes | |
| geof:asGeoJSON | 1x ogc:geomLiteral | Geometry | geo:geoJSONLiteral | geo:geoJSONLiteral | Yes | Yes | |
| geof:asGML | 1x ogc:geomLiteral, 1x xsd:string | Geometry | geo:gmlLiteral | geo:gmlLiteral | Yes | Yes | |
| geof:asKML | 1x ogc:geomLiteral | Geometry | geo:kmlLiteral | geo:kmlLiteral | Yes | Yes | |
| geof:asWKT | 1x ogc:geomLiteral | Geometry | geo:wktLiteral | geo:wktLiteral | Yes | Yes | |
| Extent functions | | | | | | | |
| geof:getSRID | 1x ogc:geomLiteral | Geometry | xsd:anyURI | xsd:anyURI | Yes | Yes | |
| geof:maxX | 1x ogc:geomLiteral | Geometry | xsd:double | xsd:double | Yes | Yes | |
| geof:maxY | 1x ogc:geomLiteral | Geometry | xsd:double | xsd:double | Yes | Yes | |
| geof:maxZ | 1x ogc:geomLiteral | Geometry | xsd:double | xsd:double | Yes | Yes | |
| geof:minX | 1x ogc:geomLiteral | Geometry | xsd:double | xsd:double | Yes | Yes | |

| Function Name | Input Parameters | Valid Input Types | Output Datatype | Output Datatype Subtypes | 2D | 3D | Comment |
|------------------------|-----------------------|-------------------|-----------------|--------------------------|-----|-----|---------|
| geof:minY | 1x ogc:geomLiteral | Geometry | xsd:double | xsd:double | Yes | Yes | |
| geof:minZ | 1x ogc:geomLiteral | Geometry | xsd:double | xsd:double | Yes | Yes | |
| Other Functions | | | | | | | |
| geof:relate | 2x ogc:geomLiteral | | xsd:string | xsd:string | Yes | Yes | |

Annex C - GeoSPARQL Examples (informative)

C.0 Overview

This Annex provides examples of the GeoSPARQL ontology and functions. In addition to these, extended examples are provided separately by the GeoSPARQL 1.1 profile, see the [GeoSPARQL Standard structure](#) for the link to those examples.

C.1 RDF Examples

This Section illustrates GeoSPARQL ontology modelling with extended examples.

C.1.1 Classes

C.1.1.1 *SpatialObject*

The *SpatialObject* class is defined in [Section 6.2.1](#).

C.1.1.1.1 Basic use

Basic use (as per the example in the class definition)

```
eg:x
  a geo:SpatialObject ;
  skos:prefLabel "Object X";
.
```

NOTE

It is unlikely that users of GeoSPARQL will create many instances of *geo:SpatialObject* as its two more concrete subclasses, *geo:Feature* & *geo:Geometry*, are more directly relatable to real-world phenomena and use.

C.1.1.1.2 Size Properties

The "size" properties - *geo:hasSize*, *geo:hasMetricSize*, *geo:hasLength*, *geo:hasMetricLength*, *geo:hasPerimeterLength*, *geo:hasMetricPerimeterLength*, *geo:hasArea*, *geo:hasMetricArea*, *geo:hasVolume* and *geo:hasMetricVolume* - are all applicable to instances of *geo:SpatialObject* although, as per the note in the section above, they are likely to be used with *geo:Feature* & *geo:Geometry* instances.

```
@prefix qudt: <http://qudt.org/schema/qudt/> .
@prefix unit: <http://qudt.org/vocab/unit/> .

eg:moreton-island
  a geo:SpatialObject ;

  skos:prefLabel "Moreton Island" ;
  rdfs:seeAlso "https://en.wikipedia.org/wiki/Moreton_Island"^^xsd:anyURI ;

  geo:hasPerimeterLength [
    qudt:numericValue "92.367"^^xsd:float ;
    qudt:unit unit:KiloM ;
  ];
  geo:hasMetricPerimeterLength "92367"^^xsd:double ;
.
```


Here a spatial object, Moreton Island, has the distance of its coastline given with two properties: `geo:hasPerimeterLength` & `geo:hasMetricPerimeterLength`. The object for the first is a Blank Node with a QUDT value property of 92.367 and a QUDT unit property of `unit:KiloM` (kilometre). The object for the second is the literal `92367` (a double) which is, by the property's definition, a number of metres.

The use of the *Quantities, Units, Dimensions and Types (QUDT)* ontology^[12] and its `qudt:numericValue` & `qudt:unit` is just one of many possible ways to convey the value of `geo:hasPerimeterLength` and any subproperty of `geo:hasSize`.

C.1.1.2 Feature

The `Feature` class is defined in [Section 6.2.2](#).

C.1.1.2.1 Basic use

```
eg:x
  a geo:Feature ;
  skos:prefLabel "Feature X" ;
.
```

Here a `Feature` is declared and given a preferred label.

C.1.1.2.2 A Feature related to a Geometry

```
eg:x
  a geo:Feature ;
  skos:prefLabel "Feature X" ;
  geo:hasGeometry [
    geo:asWKT "MULTIPOLYGON (((149.06016 -35.23610, 149.06062 -35.23604, ... ,
149.06016 -35.23610)))"^^geo:wktLiteral ;
  ] ;
.
```

Here a `geo:Feature` is declared, given a preferred label and a Geometry for that `geo:Feature` is indicated with the use of `geo:hasGeometry`. The Geometry indicated is described using a *Well-Known Text* literal value, indicated by the property `geo:asWKT` and the literal type `geo:wktLiteral`.

C.1.1.2.3 Feature with Geometry and size (area)

```

eg:x
  a geo:Feature ;
  skos:prefLabel "Feature X" ;
  geo:hasGeometry [
    geo:asWKT "MULTIPOLYGON (((149.06016 -35.23610, 149.06062 -35.23604, ... ,
149.06016 -35.23610)))"^^geo:wktLiteral ;
  ] ;
  geo:hasMetricArea "8.9E4"^^xsd:double ;
.

```

This example and the example below (B 1.1.2.4) show the same [Section 6.2.2](#), but with a different specification of its area. This example shows the recommended way to express size: by using a subproperty of [Section 6.3.2](#) (in this case, [\[Property: geo:MetricArea\]](#)). These subproperties have fixed units based on meter (the unit of distance in the International System of Units).

C.1.1.2.4 Feature with Geometry and non-metric size

```

@prefix qudt: <http://qudt.org/schema/qudt/> .

eg:x
  a geo:Feature ;
  skos:prefLabel "Feature X";
  geo:hasGeometry [
    geo:asWKT "MULTIPOLYGON (((149.06016 -35.23610, 149.06062 -35.23604, ... ,
149.06016 -35.23610)))"^^geo:wktLiteral ;
  ] ;
  geo:hasArea [
    qudt:numericValue "2.2E5"^^xsd:double ;
    qudt:unit <http://qudt.org/vocab/unit/AC> ; # international acre
  ] ;
.

```

Here a [Section 6.2.2](#) is described as per the previous example but its area is expressed in non-metric units: the acre.

C.1.1.2.5 Feature with two different Geometry instances indicated

```

eg:x
  a geo:Feature ;
  skos:prefLabel "Feature X";
  geo:hasGeometry [
    rdfs:label "Official boundary" ;
    rdfs:comment "Official boundary from the Department of Xxx" ;
    geo:asWKT "MULTIPOLYGON (((149.06016 -35.23610, 149.06062 -35.23604, ... ,
149.06016 -35.23610)))"^^geo:wktLiteral ;
  ] ,
  [
    rdfs:label "Unofficial boundary" ;
    rdfs:comment "Unofficial boundary as actually used by everyone" ;
    geo:asWKT "MULTIPOLYGON (((149.06016 -35.23610, 149.06062 -35.23604, ... ,
149.06016 -35.23610)))"^^geo:wktLiteral ;
  ] ;
.

```

In this example, **Feature X** has two different **Geometry** instances indicated with their different explained in annotation properties. No GeoSPARQL ontology properties are used to indicate a difference in these **Geometry** instances thus machine use of this **Feature** would not be easily able to differentiate them.

C.1.1.2.6 **Feature** with two different **Geometry** instances with different property values

```

eg:x
  a geo:Feature ;
  skos:prefLabel "Feature X";
  geo:hasGeometry [
    geo:hasMetricSpatialResolution "100"^^xsd:double ;
    geo:asWKT "MULTIPOLYGON (((149.0601 -35.2361, 149.0606 -35.2360, ... ,
149.0601 -35.2361)))"^^geo:wktLiteral ;
  ] ,
  [
    geo:hasMetricSpatialResolution "5"^^xsd:double ;
    geo:asWKT "MULTIPOLYGON (((149.06016 -35.23610, 149.06062 -35.23604, ... ,
149.06016 -35.23610)))"^^geo:wktLiteral ;
  ] ;
.

```

In this example, **Feature X** has two different **Geometry** instances indicated with different spatial resolutions. Machine use of this **Feature** would be able to differentiate the two **Geometry** instances based on this use of <<.

C.1.1.2.7 **Feature** with non-metric size

```

@prefix dbp: <http://dbpedia.org/resource/> .
@prefix qudt: <http://qudt.org/schema/qudt/> .

ex:Seleucia_Artemita
  a geo:Feature ;
  skos:prefLabel "The route from Seleucia to Artemita"@en ;
  geo:hasLength [
    qudt:unit ex:Schoenus ;
    qudt:value "15"^^xsd:integer ;
  ]
.
ex:Schoenus
  a qudt:Unit;
  skos:exactMatch dbp:Schoenus;
.

```

In this example it is not possible to convert the length of the feature to meters, because the historical length unit does not have a known precise conversion factor.

C.1.1.2.8 **Feature** with two different types of **Geometry** instances

```

eg:x
  a geo:Feature ;
  skos:prefLabel "Feature X";
  geo:hasGeometry [
    geo:asWKT "POLYGON ((149.06016 -35.23610, 149.060620 -35.236043, ... ,
149.06016 -35.23610))"^^geo:wktLiteral ;
  ] ;
  geo:hasCentroid [
    geo:asWKT "POINT (149.06017784 -35.23612321)"^^geo:WktLiteral ;
  ] ;
.

```

Here a **Feature** instance has two geometries, one indicated with the general property **hasGeometry** and a second indicated with the specialised property **hasCentroid** which suggests the role that the indicated geometry plays. Note that while **hasGeometry** may indicate any type of **Geometry**, **hasCentroid** should only be used to indicate a point geometry. It may be informally inferred that the polygonal geometry is the **Feature** instance's boundary.

C.1.1.2.9 **Feature** with multiple sizes

```

ex:lake-x
  a geo:Feature ;
  skos:prefLabel "Lake X" ;
  eg:hasFeatureCategory <http://example.com/cat/lake> ;
  geo:hasMetricArea "9.26E4"^^xsd:double ;
  geo:hasMetricVolume "6E5"^^xsd:double ;
.

```

This example shows a **Feature** instance with area and volume declared. A categorization of the Feature is given through the use of the **eg:hasFeatureCategory** dummy property which, along with the Feature's preferred label, indicate that this Feature is a lake. Having both an area and a volume makes sense for a lake.

C.1.1.3 Geometry

The **Geometry** class is defined in [Section 8.2.1](#).

C.1.1.3.1 Basic Use

```

eg:y a geo:Geometry ;
  skos:prefLabel "Geometry Y";
.

```

Here a **Geometry** is declared and given a preferred label.

From GeoSPARQL 1.0 use, the most commonly observed use of a **Geometry** is in relation to a **Feature** as per the example in [\[B 1.1.2.2 A Feature related to a Geometry\]](#) and often the **Geometry** is indirectly declared by the use of **hasGeometry** on the **Feature** instance indicating a Blank Node, however it is entirely possible to declare **Geometry** instances without any **Feature** instances. The next basic example declares a **Geometry** instance with an demonstration absolute URI and data.

```

<https://example.com/geometry/y>
  a geo:Geometry ;
  skos:prefLabel "Geometry Y";
  geo:asWKT "MULTIPOLYGON (((149.06016 -35.23610, 149.060620 -35.236043, ... ,
149.06016 -35.23610)))"^^geo:wktLiteral ;
.

```

Here the **Geometry** instance has data in WKT form and, since no CRS is declared, WGS84 is the assumed, default, CRS.

C.1.1.3.2 A Geometry with multiple serializations

```

eg:x
  a geo:Feature ;
  skos:prefLabel "Feature X";
  geo:hasGeometry [
    geo:asWKT "<http://www.opengis.net/def/crs/EPSG/0/4326> MULTIPOLYGON
(((149.06016 -35.23610, 149.060620 -35.236043, ... , 149.06016
-35.23610)))"^^geo:wktLiteral ;
    geo:asDGGS "<https://w3id.org/dggs/aspix> CELLLIST ((R1234 R1235 R1236 ...
R1256))"^^eg:auspidxDggsLiteral ;
  ] ;
.

```

Here a single **Geometry**, linked to a **Feature** instance, is expressed using two different serializations: Well-known Text and the example AusPIX DGGS. Note that the latter is not formally defined in GeoSPARQL.

C.1.1.3.3 **Geometry** with scalar spatial property

```

eg:x
  a geo:Feature ;
  skos:prefLabel "Feature X";
  geo:hasGeometry eg:x-geo ;
.

eg:x-geo
  a geo:Geometry ;
  geo:asWKT "MULTIPOLYGON (((149.06016 -35.23610, 149.060620 -35.236043, ... ,
149.06016 -35.23610)))"^^geo:wktLiteral ;
  geo:hasMetricArea "8.7E4"^^xsd:double;
.

```

This example shows a Feature, **eg:x**, with a Geometry, **eg:x-geo**, which has both a serialization (WKT) indicated with the predicate **geo:asWKT** and a scalar area indicated with the predicate **geo:hasMetricArea**. While it is entirely possible that scalar areas can be calculated from polygons, it may be efficient to store a pre-calculated scalar area in addition to the polygon. Perhaps the polygon is large and detailed and a one-time calculation with results stored is efficient for repeated use.

This use of a scalar spatial measurement property with a Geometry, here **geo:hasMetricArea**, is possible since the domain of such properties is **geo:SpatialObject**, the superclass of both **geo:Feature** and **geo:Geometry**.

B 1.1.5 **SpatialObjectCollection**

geo:SpatialObjectCollection isn't really intended to be implemented - it's essentially an abstract class - therefore no examples of its use are given. See the following two sections for examples of the concrete **geo:FeatureCollection** & **geo:GeometryCollection** classes.

B 1.1.6 FeatureCollection

This example shows a **FeatureCollection** instance containing 3 **Feature** instances.

```
ex:fc-x
  a geo:FeatureCollection ;
  dcterms:title "Feature Collection X" ;
  rdfs:member
    ex:feature-something ,
    ex:feature-other ,
    ex:feature-another ;
.
```

All of the GeoSPARQL collection classes are unordered since they are subclasses of the generic **rdfs:Container**, however implementers should consider that there are many ways to order the members of a **FeatureCollection** such as the **Feature** instances labels, their areas, geometries or any other property.

B 1.1.7 GeometryCollection

This example shows a **GeometryCollection** instance containing 3 **Geometry** instances.

```
ex:gc-x
  a geo:GeometryCollection ;
  dcterms:title "Geometry Collection X" ;
  rdfs:member
    ex:geometry-shape ,
    ex:geometry-othershape ,
    ex:geometry-anothershape ;
.
```

As per **FeatureCollection**, the **GeometryCollection** itself doesn't impose any ordering on its member **Geometry** instances, however there are many ways to order them, based on their own properties.

C.1.2 Properties

C.1.2.1 Spatial Object Properties

See the section [C.1.1.1.2 Size Properties](#) above.

C.1.2.2 Feature Properties

This example shows a **geo:Feature** instance with each of the properties defined in [Section 6.4](#) used, except for the properties **geo:hasMetricSize** and **geo:hasSize**, that are intended to be used through their subproperties and **geo:hasMetricPerimeterLength** and **geo:hasPerimeterLength** which are exemplified in [C.1.1.1.2 Size Properties](#).

```
@prefix qudt: <http://qudt.org/schema/qudt/> .
```

```
eg:x
```

```
  a geo:Feature ;
  skos:preferredLabel "Feature X" ;
  geo:hasGeometry [
    geo:asWKT "<http://www.opengis.net/def/crs/EPSSG/0/4326> POLYGON ((149.06016
-35.23610, ... , 149.06016 -35.23610)))"^^geo:wktLiteral ;
  ] ;
  geo:hasDefaultGeometry [
    geo:asWKT "<http://www.opengis.net/def/crs/EPSSG/0/4326> POLYGON ((149.0601
-35.2361, ... , 149.0601 -35.2361)))"^^geo:wktLiteral ;
  ] ;
  geo:hasMetricLength "355"^^xsd:double ;
  geo:hasLength [
    qudt:numericValue 355 ;
    qudt:unit <http://qudt.org/vocab/unit/M> ; # meter
  ] ;
  geo:hasMetricArea "8.7E4"^^xsd:double ;
  geo:hasArea [
    qudt:numericValue 8.7 ;
    qudt:unit <http://qudt.org/vocab/unit/HA> ; # hectare
  ] ;
  geo:hasMetricVolume "624432"^^xsd:double ;
  geo:hasVolume [
    qudt:numericValue 624432 ;
    qudt:unit <http://qudt.org/vocab/unit/M3> ; # cubic meter
  ] ;
  geo:hasCentroid [
    geo:asWKT "POINT (149.06017 -35.23612)"^^geo:wktLiteral ;
  ] ;
  geo:hasBoundingBox [
    geo:asWKT "<http://www.opengis.net/def/crs/EPSSG/0/4326> POLYGON ((149.060
-35.236, ... , 149.060 -35.236)))"^^geo:wktLiteral ;
  ] ;
  geo:hasMetricSpatialResolution "5"^^xsd:double ;
  geo:hasSpatialResolution [
    qudt:numericValue 5 ;
    qudt:unit <http://qudt.org/vocab/unit/M> ; # meter
  ] ;
.
```

The properties defined for this example's **Feature** instance are vaguely aligned in that the values are not real but are not unrealistic either. It is outside the scope of GeoSPARQL to validate **Feature** instances' property values.

Note that this **Feature** has a 2D **Geometry** and yet a property indicating a scalar volume: **geo:hasVolume**. Used in this way, the scalar property is indicating information that cannot be calculated from other information about the **Feature** such as its geometry. Perhaps a volume for the

feature has been estimated or measured in such a way that a 3D geometry was not created.

C.1.2.3 Geometry Properties

This example shows a **Geometry** instance, a Blank Node, declared in relation to a **Feature** instance, with each of the properties defined in [Section 8.3](#) used.

```
@prefix qudt: <http://qudt.org/schema/qudt/> .
@prefix unit: <http://qudt.org/vocab/unit/> .

eg:x
  a geo:Feature ;
  geo:hasGeometry [
    skos:prefLabel "Geometry Y" ;
    geo:dimension 2 ;
    geo:coordinateDimension 2 ;
    geo:spatialDimension 2 ;
    geo:isEmpty false ;
    geo:isSimple true ;
    geo:hasSerialization "<http://www.opengis.net/def/crs/EPSSG/0/4326> POLYGON
((149.060 -35.236, ... , 149.060 -35.236)))"^^geo:wktLiteral ;
    geo:hasSpatialAccuracy [
      qudt:numericValue "30"^^xsd:float ;
      qudt:unit unit:CentiM ; # centimetres
    ] ;
    geo:hasMetricSpatialAccuracy "0.3"^^xsd:double ;
  ] ;
.
```

In this example, each of the standards properties defined for a **Geometry** instance has realistic values, for example, the **is empty** is set to **false** since the **Geometry** contains information.

C.1.2.4 Geometry Serializations

This section shows a **Geometry** instance for a **Feature** instance which is represented in all supported GeoSPARQL serializations. The geometry values given are real geometry values and approximate [Moreton Island](#) in Queensland, Australia.

Note that the concrete DGGs serialization used is for example purposes only as it is not formally defined in GeoSPARQL.

```
eg:x
  a geo:Feature ;
  geo:hasGeometry [
    geo:asWKT ""<http://www.opengis.net/def/crs/EPSSG/0/4326>
      POLYGON ((
        153.3610112 -27.0621757,
        153.3658177 -27.1990606,
        153.421436 -27.3406573,
```

```

153.4269292 -27.3607835,
153.4434087 -27.3315078,
153.4183848 -27.2913403,
153.4189391 -27.2039578,
153.4673476 -27.0267166,
153.3610112 -27.0621757
))""^geo:wktLiteral ;

geo:asGML ""<gml:Polygon
  srsName="http://www.opengis.net/def/crs/EPSG/0/4326">
  <gml:exterior>
    <gml:LinearRing>
      <gml:posList>
        -27.0621757 153.3610112
        -27.1990606 153.3658177
        -27.3406573 153.421436
        -27.3607835 153.4269292
        -27.3315078 153.4434087
        -27.2913403 153.4183848
        -27.2039578 153.4189391
        -27.0267166 153.4673476
        -27.0621757 153.3610112
      </gml:posList>
    </gml:LinearRing>
  </gml:exterior>
</gml:Polygon>""^go:gmlLiteral ;

geo:asKML ""<Polygon>
  <outerBoundaryIs>
    <LinearRing>
      <coordinates>
        153.3610112,-27.0621757
        153.3658177,-27.1990606
        153.421436,-27.3406573
        153.4269292,-27.3607835
        153.4434087,-27.3315078
        153.4183848,-27.2913403
        153.4189391,-27.2039578
        153.4673476,-27.0267166
        153.3610112,-27.0621757
      </coordinates>
    </LinearRing>
  </outerBoundaryIs>
</Polygon>""^go:kmlLiteral ;

geo:asGeoJSON ""{
  "type": "Polygon",
  "coordinates": [[
    [153.3610112, -27.0621757],
    [153.3658177, -27.1990606],
    [153.421436, -27.3406573],

```

```
[153.4269292, -27.3607835],  
[153.4434087, -27.3315078],  
[153.4183848, -27.2913403],  
[153.4189391, -27.2039578],  
[153.4673476, -27.0267166],  
[153.3610112, -27.0621757]  
]]  
}""^^geo:geoJSONLiteral ;
```

```
geo:asDGGs ""CELLLIST ((R8346031 R8346034 R8346037  
R83460058 R83460065 R83460068 R83460072 R83460073 R83460074 R83460075  
R83460076 R83460077 R83460078 R83460080 R83460081 R83460082 R83460083 R83460084  
R83460085 R83460086 R83460087 R83460088 R83460302 R83460305 R83460308 R83460320  
R83460321 R83460323 R83460324 R83460326 R83460327 R83460332 R83460335 R83460338  
R83460350 R83460353 R83460356 R83460362 R83460365 R83460380 R83460610 R83460611  
R83460612 R83460613 R83460614 R83460615 R83460617 R83460618 R83460641 R83460642  
R83460644 R83460645 R83460648 R83460672 R83460686 R83463020 R83463021 R834600487  
R834600488 R834600557 R834600558 R834600564 R834600565 R834600566 R834600567  
R834600568 R834600571 R834600572 R834600573 R834600574 R834600575 R834600576  
R834600577 R834600578 R834600628 R834600705 R834600706 R834600707 R834600708  
R834600712 R834600713 R834600714 R834600715 R834600716 R834600717 R834600718  
R834601334 R834601335 R834601336 R834601337 R834601338 R834601360 R834601361  
R834601363 R834601364 R834601366 R834601367 R834601600 R834601601 R834601603  
R834601606 R834601630 R834601633 R834603220 R834603221 R834603223 R834603224  
R834603226 R834603227 R834603250 R834603251 R834603253 R834603256 R834603280  
R834603283 R834603510 R834603511 R834603512 R834603513 R834603514 R834603515  
R834603516 R834603517 R834603540 R834603541 R834603543 R834603544 R834603546  
R834603547 R834603570 R834603573 R834603576 R834603681 R834603682 R834603684  
R834603685 R834603687 R834603688 R834603810 R834603830 R834603831 R834603832  
R834603833 R834603834 R834603835 R834603836 R834603837 R834603860 R834603861  
R834603863 R834603864 R834603866 R834603867 R834606021 R834606022 R834606024
```

```

R834606025
R834606164
R834606230
R834606402
R834606475
R834606533
R834606718
R834606757
R834606800
R834606834
R834606874
R834630231
R834630241
R834630261
R834630273
R834630276
R834630502))""^eg:auspixDggsLiteral ;
] ;
.

```

C.2 Example SPARQL Queries & Rules

This Section provides example data and then illustrates the use of GeoSPARQL functions and the application of rules with that data.

C.2.1 Example Data

The following RDF data (Turtle format) encodes application-specific spatial data. The resulting spatial data is illustrated in the figure below. The RDF statements define the feature class `my:PlaceOfInterest`, and two properties are created for associating geometries with features: `my:hasExactGeometry` and `my:hasPointGeometry`. `my:hasExactGeometry` is designated as the default geometry for the `my:PlaceOfInterest` feature class.

All the following examples use the parameter values `relation_family = Simple Features`, `serialization = WKT`, and `version = 1.0`.



Figure 4. Illustration of spatial data

```
@prefix geo: <http://www.opengis.net/ont/geosparql#> .
@prefix my: <http://example.org/ApplicationSchema#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix sf: <http://www.opengis.net/ont/sf#> .

my:PlaceOfInterest a rdfs:Class ;
  rdfs:subClassOf geo:Feature .

my:A a my:PlaceOfInterest ;
  my:hasExactGeometry my:AExactGeom ;
  my:hasPointGeometry my:APointGeom .

my:B a my:PlaceOfInterest ;
  my:hasExactGeometry my:BExactGeom ;
  my:hasPointGeometry my:BPointGeom .

my:C a my:PlaceOfInterest ;
```

```

my:hasExactGeometry my:CExactGeom ;
my:hasPointGeometry my:CPointGeom .

my:D a my:PlaceOfInterest ;
  my:hasExactGeometry my:DExactGeom ;
  my:hasPointGeometry my:DPointGeom .

my:E a my:PlaceOfInterest ;
  my:hasExactGeometry my:EExactGeom .

my:F a my:PlaceOfInterest ;
  my:hasExactGeometry my:FExactGeom .

my:hasExactGeometry a rdf:Property ;
  rdfs:subPropertyOf geo:hasDefaultGeometry,
    geo:hasGeometry .

my:hasPointGeometry a rdf:Property ;
  rdfs:subPropertyOf geo:hasGeometry .

my:AExactGeom a sf:Polygon ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    Polygon((-83.6 34.1, -83.2 34.1, -83.2 34.5,
      -83.6 34.5, -83.6 34.1))""^^geo:wktLiteral.

my:APointGeom a sf:Point ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    Point(-83.4 34.3)""^^geo:wktLiteral.

my:BExactGeom a sf:Polygon ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    Polygon((-83.6 34.1, -83.4 34.1, -83.4 34.3,
      -83.6 34.3, -83.6 34.1))""^^geo:wktLiteral.

my:BPointGeom a sf:Point ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    Point(-83.5 34.2)""^^geo:wktLiteral.

my:CExactGeom a sf:Polygon ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    Polygon((-83.2 34.3, -83.0 34.3, -83.0 34.5,
      -83.2 34.5, -83.2 34.3))""^^geo:wktLiteral.

my:CPointGeom a sf:Point ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    Point(-83.1 34.4)""^^geo:wktLiteral.

my:DExactGeom a sf:Polygon ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    Polygon((-83.3 34.0, -83.1 34.0, -83.1 34.2,
      -83.3 34.2, -83.3 34.0))""^^geo:wktLiteral.

```

```

my:DPointGeom a sf:Point ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    Point(-83.2 34.1)""^^geo:wktLiteral.

my:EExactGeom a sf:LineString ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    LineString(-83.4 34.0, -83.3 34.3)""^^geo:wktLiteral.

my:FExactGeom a sf:Point ;
  geo:asWKT ""<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
    Point(-83.4 34.4)""^^geo:wktLiteral.

```

C.2.2 Example Queries

This Section illustrates the use of GeoSPARQL functions through a series of example queries.

C.2.2.1

Find all features that feature `my:A` contains, where spatial calculations are based on `my:hasExactGeometry`.

```

PREFIX my: <http://example.org/ApplicationSchema#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX geof: <http://www.opengis.net/def/function/geosparql/>

SELECT ?f
WHERE {
  my:A my:hasExactGeometry ?aGeom .
  ?aGeom geo:asWKT ?aWKT .
  ?f my:hasExactGeometry ?fGeom .
  ?fGeom geo:asWKT ?fWKT .

  FILTER (
    geof:sfContains(?aWKT, ?fWKT) &&
    !sameTerm(?aGeom, ?fGeom)
  )
}

```

Result:

| ?f |
|------|
| my:B |
| my:F |

C.2.2.2

Find all features that are within a transient bounding box geometry, where spatial calculations are based on `my:hasPointGeometry`.

```
PREFIX my: <http://example.org/ApplicationSchema#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX geof: <http://www.opengis.net/def/function/geosparql/>

SELECT ?f
WHERE {
  ?f my:hasPointGeometry ?fGeom .
  ?fGeom geo:asWKT ?fWKT .
  FILTER (
    geof:sfWithin(
      ?fWKT,
      "<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
      Polygon ((-83.4 34.0, -83.1 34.0,
                -83.1 34.2, -83.4 34.2,
                -83.4 34.0))"^^geo:wktLiteral
    )
  )
}
```

Result:

| ?f |
|-------------------|
| <code>my:D</code> |

C.2.2.3

Find all features that touch the union of feature `my:A` and feature `my:D`, where computations are based on `my:hasExactGeometry`.


```

PREFIX my: <http://example.org/ApplicationSchema#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX geof: <http://www.opengis.net/def/function/geosparql/>

SELECT ?f
WHERE {
  ?f my:hasExactGeometry ?fGeom .
  ?fGeom geo:asWKT ?fWKT .
  my:A my:hasExactGeometry ?aGeom .
  ?aGeom geo:asWKT ?aWKT .
  my:D my:hasExactGeometry ?dGeom .
  ?dGeom geo:asWKT ?dWKT .
  FILTER (
    geof:sfTouches(
      ?fWKT,
      geof:union(?aWKT, ?dWKT)
    )
  )
}

```

Result:

| ?f |
|------|
| my:C |

C.2.2.4

Find the 3 closest features to feature my:C, where computations are based on my:hasExactGeometry.

```

PREFIX uom: <http://www.opengis.net/def/uom/OGC/1.0/>
PREFIX my: <http://example.org/ApplicationSchema#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX geof: <http://www.opengis.net/def/geosparql/function>

SELECT ?f
WHERE {
  my:C my:hasExactGeometry ?cGeom .
  ?cGeom geo:asWKT ?cWKT .
  ?f my:hasExactGeometry ?fGeom .
  ?fGeom geo:asWKT ?fWKT .
  FILTER (?fGeom != ?cGeom)
}
ORDER BY ASC (geof:distance(?cWKT, ?fWKT, uom:metre))
LIMIT 3

```

Result:

?f

my:A

my:D

my:E

C.2.2.5

Find the maximum and minimum coordinates of a given set of geometries.

```
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX geof: <http://www.opengis.net/def/function/geosparql/>

SELECT ?minX ?minY ?minZ ?maxX ?maxY ?maxZ
WHERE {
  BIND ("<http://www.opengis.net/def/crs/OGC/1.3/CRS84>
        Polygon Z((-83.4 34.0 0, -83.1 34.0 1,
                    -83.1 34.2 1, -83.4 34.2 1,
                    -83.4 34.0 0))"^^geo:wktLiteral) AS ?testgeom)
  BIND(geof:minX(?testgeom) AS ?minX)
  BIND(geof:maxX(?testgeom) AS ?maxX)
  BIND(geof:minY(?testgeom) AS ?minY)
  BIND(geof:maxY(?testgeom) AS ?maxY)
  BIND(geof:maxZ(?testgeom) AS ?maxZ)
  BIND(geof:minZ(?testgeom) AS ?minZ)
}
```

Result:

| ?minX | ?minY | ?minZ | ?maxX | ?maxY | ?maxZ |
|-------|-------|-------|-------|-------|-------|
| -83.4 | 34.0 | 0 | -83.1 | 34.2 | 1 |

C.2.3 Example Rule Application

This section illustrates the query transformation strategy for implementing GeoSPARQL rules.

C.2.3.1

Find all features or geometries that overlap feature my:A.

Original Query:

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

SELECT ?f
WHERE { ?f geo:sfOverlaps my:A }
```

Transformed Query (application of transformation rule geor:sfOverlaps):

```
PREFIX my: <http://example.org/ApplicationSchema#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>
PREFIX geof: <http://www.opengis.net/def/function/geosparql/>

SELECT ?f
WHERE {
  { # check for asserted statement
    ?f geo:sfOverlaps my:A }
  UNION
  { # feature ⊆ feature
    ?f geo:hasDefaultGeometry ?fGeom .
    ?fGeom geo:asWKT ?fSerial .
    my:A geo:hasDefaultGeometry ?aGeom .
    ?aGeom geo:asWKT ?aSerial .
    FILTER (geof:sfOverlaps(?fSerial, ?aSerial))
  }
  UNION
  { # feature ⊆ geometry
    ?f geo:hasDefaultGeometry ?fGeom .
    ?fGeom geo:asWKT ?fSerial .
    my:A geo:asWKT ?aSerial .
    FILTER (geof:sfOverlaps(?fSerial, ?aSerial))
  }
  UNION
  { # geometry ⊆ feature
    ?f geo:asWKT ?fSerial .
    my:A geo:hasDefaultGeometry ?aGeom .
    ?aGeom geo:asWKT ?aSerial .
    FILTER (geof:sfOverlaps(?fSerial, ?aSerial))
  }
  UNION
  { # geometry ⊆ geometry
    ?f geo:asWKT ?fSerial .
    my:A geo:asWKT ?aSerial .
    FILTER (geof:sfOverlaps(?fSerial, ?aSerial))
  }
}
```

Result:

| ?f |
|---------------|
| my:D |
| my:DExactGeom |
| my:E |
| my:EExactGeom |

C.2.4 Example Geometry Serialization Conversion Functions

C.1.2.2.1 `geof:asWKT`

For the geometry literal values in [\[C.1.2.3 Geometry Serializations\]](#):

Application of the function `geof:asWKT` to the GML, KML, GeoJSON and DGGs literals should return WKT literal and similarly for each of the other conversion methods, `geof:asGML`, `geof:asKML`, `geof:asGeoJSON` & `geof:asDGGs`.

Note that the application of `geof:asDGGs` requires a `specificDggsDatatype` parameter which indicates the particular DGGs literal form being converted to. In the case of [\[C.1.2.3 Geometry Serializations\]](#), this value would be `eg:auspixDggsLiteral`, the example datatype of the AusPIX DGGs.

Unresolved directive in 00-GeoSPARQL.adoc - include::19-Annex-D.adoc[]

Annex E - Alignments (informative)

E.0 Overview

This Annex provides alignments of GeoSPARQL to other well known ontologies that are either commonly used with GeoSPARQL or could be.

The prefixes used for the ontologies mapped to in all following sections are given in the following table.

| | |
|----------------|---|
| dcterms: | http://purl.org/dc/terms/ |
| geo: | http://www.opengis.net/ont/geosparql# |
| geom: | http://geovocab.org/geometry# |
| gn: | https://www.geonames.org/ontology# |
| juso: | http://rdfs.co/juso/ |
| lgd: | http://linkedgeodata.org/ontology/ |
| locn: | https://www.w3.org/ns/locn |
| osm: | https://w3id.org/openstreetmap/terms# |
| osmm: | https://www.openstreetmap.org/meta/ |
| osmt: | https://wiki.openstreetmap.org/wiki/Key: |
| pos: | http://www.w3.org/2003/01/geo/wgs84_pos# |
| prov: | http://www.w3.org/ns/prov# |
| rdf: | http://www.w3.org/1999/02/22-rdf-syntax-ns# |
| rdfs: | http://www.w3.org/2000/01/rdf-schema# |
| sdo: | https://schema.org |
| sosa: | http://www.w3.org/ns/sosa/ |
| spatialuk: | http://data.ordnancesurvey.co.uk/ontology/spatialrelations/ |
| spatialukgeom: | http://data.ordnancesurvey.co.uk/ontology/geometry/ |
| spatial: | http://geovocab.org/spatial# |
| ssn: | http://www.w3.org/ns/ssn/ |
| time: | http://www.w3.org/2006/time# |
| wdt: | http://www.wikidata.org/entity/ |

E.1 ISA Programme Location Core Vocabulary (LOCN)

LOCN Source: <https://www.w3.org/ns/locn>

The LOCN specification provides notes on the use of GeoSPARQL literals (see <https://www.w3.org/ns/locn#changes>).

| From Element | Mapping relation | To Element | Notes |
|---------------------------|----------------------------------|-------------------------------|--|
| <code>geo:Feature</code> | <code>rdfs:subClassOf</code> | <code>dcterms:Location</code> | LOCN states that <code>dcterms:Location</code> "represents any location, irrespective of size or other restriction", thus it is a superclass of <code>geo:Feature</code> |
| <code>locn:Address</code> | <code>rdfs:subClassOf</code> | <code>geo:Feature</code> | Although LOCN indicates no spatial or geometry properties for <code>locn:Address</code> , <code>locn:Address</code> is clearly some specialized form of a Feature |
| <code>geo:Geometry</code> | <code>owl:equivalentClass</code> | <code>locn:Geometry</code> | The LOCN class "defines the notion of "geometry" at the conceptual level, and it shall be encoded by using different formats", so GeoSPARQL's class is equivalent. |

| From Element | Mapping relation | To Element | Notes |
|-----------------|-------------------|---------------|---|
| geo:hasGeometry | owl:subPropertyOf | locn:geometry | The LOCN property notes say "Depending on how a geometry is encoded, the range of this property may be one of...". GeoSPARQL's property is indicates only a geo:Geometry class instances, not a Literal for instnace, so GeoSPARQL's property is clearly more narrowly defined. |

E.2 WGS84 Geo Positioning: an RDF vocabulary (POS)

POS Source: <http://www.w3.org/2003/01/geo/>

| From Element | Mapping relation | To Element | Notes |
|--------------------------------|----------------------------------|-----------------------------------|--|
| <code>geo:SpatialObject</code> | <code>owl:equivalentClass</code> | <code>pos:SpatialThing</code> | Both classes are unrestricted, essentially abstract classes |
| <code>pos:Point</code> | <code>rdfs:subClassOf</code> | <code>geo:Geometry</code> | Via <code>pos:Point</code> <code>rdfs:subClassOf</code> <code>pos:SpatialThing</code> but since <code>pos:Point</code> usage notes indicate direct positioning, it is a form of geometry |
| <code>pos:Point</code> | <code>owl:equivalentClass</code> | <code>sf:Point</code> | |
| <code>pos:lat_long</code> | <code>rdfs:subPropertyOf</code> | <code>geo:hasSerialization</code> | A special datatype is not indicated for use with this property by POS, unlike GeoSPARQL's <code>geo:hasSerialization</code> object literals |
| <code>pos:location</code> | <code>rdfs:subPropertyOf</code> | <code>rdfs:hasGeometry</code> | |

E.3 Geonames Ontology (GN)

Geonames source: <http://www.geonames.org/ontology/documentation.html>

| From Element | Mapping relation | To Element | Notes |
|--------------------|------------------------|----------------|--|
| gn:Feature | owl:equivalentClass | geo:Feature | |
| gn:GeonamesFeature | rdfs:subClassOf | geo:Feature | The GN class is defined as "A feature described in geonames database..." |
| geo:Feature | rdfs:subClassOf | gn:Class | The GN class' definition reads "A class of features" |
| gn:locatedIn | owl:equivalentProperty | geo:sfWithin | |
| gn:nearby | rdfs:subPropertyOf | geo:sfDisjoint | A gn:nearby B means A is not within or touching B. The only close SF property is disjoint |
| gn:neighbour | owl:equivalentProperty | geo:sfTouches | |

E.4 NeoGeo Vocabulary

NeoGeo Source: <http://geovocab.org/> / <http://geovocab.org/doc/neogeo/>

| From Element | Mapping relation | To Element | Notes |
|-------------------------|---------------------|------------------------|---|
| spatial:Feature | owl:equivalentClass | geo:Feature | |
| spatial:C | rdfs:subPropertyOf | geo:rcc8ec | Sub proerty not equivalent property since the NeoGeo property has more restrictive domain & range |
| spatial:DR | rdfs:subPropertyOf | geo:rcc8dc | |
| spatial:EC | rdfs:subPropertyOf | geo:rcc8ec | |
| spatial:EQ | rdfs:subPropertyOf | geo:rcc8eq | |
| spatial:NTPP | rdfs:subPropertyOf | geo:rcc8ntpp | |
| spatial:NTPPi | rdfs:subPropertyOf | geo:rcc8ntppi | |
| spatial:O | rdfs:subPropertyOf | geo:sfOverlaps | |
| spatial:P | rdfs:subPropertyOf | geo:sfWithin | |
| spatial:PO | rdfs:subPropertyOf | geo:rcc8po | |
| spatial:PP | rdfs:subPropertyOf | geo:sfWithin | |
| spatial:PPi | rdfs:subPropertyOf | geo:sfContains | |
| spatial:Pi | rdfs:subPropertyOf | geo:sfContains | |
| spatial:TPP | rdfs:subPropertyOf | geo:rcc8tp | |
| spatial:TPPi | rdfs:subPropertyOf | geo::rcc8tpi | |
| geom:Geometry | owl:equivalentClass | geo:Geometry | |
| geom:BoundingBox | rdfs:subClassOf | geo:Geometry | GeoSPARQL doesn't have a BoundingBox class but has a generic Geometry class that is the range of the geo:hasBoundigBox property |
| geom:GeometryCollection | owl:equivalentClass | geo:GeometryCollection | |
| geom:LineString | owl:equivalentClass | sf:LineString | |
| geom:LinearRing | owl:equivalentClass | sf:LinearRing | |
| geom:MultiLineString | owl:equivalentClass | sf:MultiLineString | |
| geom:MultiPoint | owl:equivalentClass | sf:MultiPoint | |
| geom:MultiPolygon | owl:equivalentClass | sf:MultiPolygon | |
| geom:Polygon | owl:equivalentClass | sf:Polygon | |
| geom:Point | owl:equivalentClass | sf:Point | |

| From Element | Mapping relation | To Element | Notes |
|-----------------|--------------------|---------------|---|
| geom:bbox | - | - | This property relates a Geometry to another Geometry and is thus not equivalent to GeoSPARQL's Feature to Geometry geom:hasBoundingBox |
| geo:hasGeometry | rdfs:subPropertyOf | geom:geometry | geo:hasGeometry has more restrictive domain |

E.5 Juso Ontology

Juso Source: <http://rdfs.co/juso/>

Juso contains mappings to GeoSPARQL but uses `owl:sameAs` which it should instead use `owl:equivalentClass`.

| From Element | Mapping relation | To Element | Notes |
|-------------------------|------------------------|-------------------|-------|
| juso:SpatialThing | owl:equivalentClass | geo:SpatialObject | |
| juso:Feature | owl:equivalentClass | geo:Feature | |
| juso:Geometry | owl:equivalentClass | geo:Geometry | |
| juso:Point | owl:equivalentClass | sf:Point | |
| juso:geometry | owl:equivalentProperty | geo:hasGeometry | |
| juso:parent | rdfs:subPropertyOf | geo:sfWithin | |
| juso:political_division | rdfs:subPropertyOf | geo:sfContains | |
| juso:within | owl:equivalentProperty | geo:sfWithin | |

E.6 Time Ontology in OWL (TIME)

TIME Source: <https://www.w3.org/TR/owl-time/>

There are no direct class or property correspondences between GeoSPARQL and TIME however class patterning is similar:

- TIME uses `time:hasTime` to indicate that something has a temporal projection
- GeoPSARQL uses `geo:hasGeometry` to indicate that a `geo:Feature` has a spatial projection

and

- TIME uses properties such as `time:inXSDDate` to indicate the position of temporal entities on a temporal reference system
- GeoSPARQL uses properties such as `geo:asWKT` to indicate the position of spatial entities (Geometries) on spatial reference systems

OWL TIME sets no domain for `time:hasTime` thus this property may be used with anything, including a GeoSPARQL `geo:Feature` so that a spati-temporal Feature may be indicated like this:

```
:flooded-area-x
  a geo:Feature ;
  geo:hasGeometry [
    a geo:Geometry ;
    geo:asWKT "POLYGON (((...)))"^^geo:wktLiteral ;
  ] ;
  time:hasTime [
    a time:ProperInterval ;
    time:hasBeginning [
      time:inXSDDate "...^^xsd:date ;
    ] ;
    time:hasEnd [
      time:inXSDDate "...^^xsd:date ;
    ] ;
  ] ;
.
```

In the above example, `:flooded-area-x` is a spatio-temporal Feature that has both a GeoSPARQL spatial projection - a `geo:Geometry` - and a temporal projection - a `time:ProperInterval` which is a specialised form of `time:TemporalEntity`.

Another possible use of TIME with GeoSPARQL is to assign temporality to individual `geo:Geometry` instances. This is allowed given `time:hasTime`'s open domain:

```
:flooded-area-x
  a geo:Feature ;
  geo:hasGeometry [
    a geo:Geometry ;
    geo:asWKT "POLYGON (((...)))"^^geo:wktLiteral ;
    time:hasTime [ ... ] ;
  ] ;
.
```

In contrast to the first example, `:flooded-area-x` is inferred to be a spatio-temporal Feature but since it is the Geometry of `:flooded-area-x` that has a temporality, it is possible to describe other Geometries of `:flooded-area-x` with other temporalities.

E.7 schema.org

schema.org Source: <https://schema.org>

| From Element | Mapping relation | To Element | Notes |
|------------------------|------------------------|-------------------|--|
| geo:Geometry | rdfs:subClassOf | sdo:GeoShape | A GeoShape can various literal geometry representation |
| sdo:GeospatialGeometry | owl:equivalentClass | geo:SpatialObject | Since GeospatialGeometry is the domain of SimpleFeature-like properties and a superclass of GeoShape |
| sdo:GeoCoordinates | rdfs:subClassOf | geo:Geometry | GoCoordinates uses direct lat, long, elevation etc properties to indicate position, not a while geometry serialization but it is nevertheless a form of a Geometry |
| sdo:geo | rdfs:subPropertyOf | geo:hasGeometry | |
| sdo:geoCoveredBy | owl:equivalentProperty | geo:ehCoveredBy | |
| sdo:geoCovers | owl:equivalentProperty | geo:ehCovers | |
| sdo:geoCrosses | owl:equivalentProperty | geo:sfCrosses | |
| sdo:geoDisjoint | owl:equivalentProperty | geo:sfDisjoint | |
| sdo:geoEquals | owl:equivalentProperty | geo:sfEquals | |
| sdo:geoIntersects | owl:equivalentProperty | geo:sfIntersects | |
| sdo:geoOverlaps | owl:equivalentProperty | geo:sfOverlaps | |
| sdo:geoTouches | owl:equivalentProperty | geo:sfTouches | |
| sdo:geoWithin | owl:equivalentProperty | geo:sfWithin | |
| sdo:Landform | rdfs:subClassOf | geo:Feature | |

E.8 Semantic Sensor Network Ontology (SSN)

SSN Source: <https://www.w3.org/TR/vocab-ssn/>

SSN and GeoSPARQL do not cover overlapping concerns directly and therefore there are no direct class or property correspondences between them, however SSN provides advice on the use of GeoSPARQL for location, see Section 7.1 (<https://www.w3.org/TR/vocab-ssn/#x7-1-location>):

GeoSPARQL ... provides a flexible and relatively complete platform for geospatial objects, that fosters interoperability between geo-datasets. To do so, these entities can be declared as instances of `geo:Feature` and geometries can be assigned to them via the `geo:hasGeometry` property. In case of classes, e.g., specific features of interests such as rivers, these can be defined as subclasses of `geo:Feature`.

E.9 DCMI Metadata Terms (DCTERMS)

DCTERMS Source: <https://www.dublincore.org/specifications/dublin-core/dcmi-terms/>

| From Element | Mapping relation | To Element | Notes |
|-------------------------------|------------------------------|-------------------------------|--|
| <code>geo:Feature</code> | <code>rdfs:SubClassOf</code> | <code>dcterms:Location</code> | A Location is a "A spatial region or named place." |
| <code>dcterms:coverage</code> | - | - | See note below table |

`dcterms:coverage` is extremely generic - "The spatial or temporal topic of the resource, spatial applicability of the resource, or jurisdiction under which the resource is relevant." - but DCTERMS indicates its range includes a `dcterms:Location`, so it is a property for indicating a `geo:Feature`, not a `geo:Geometry` and for which GeoSPARQL has no equivalent. Often, `dcterms:coverage` is used to indicate a spatial extent such as a bounding box. GeoSPARQL now provides a `geo:hasBoundingBox` property, so such a property could be used if a Bounding Box is wanted to be indicated.

DCTERMS-related geometry literals, such as the *DCMI Box Encoding Scheme*^[13] and the *DCMI Point Encoding Scheme*^[14] could be indicated as GeoSPARQL geometry literals if a literal datatype were created for each. For example, the *DCMI Point Encoding Scheme* example of "The highest point in Australia" with the literal value `east=148.26218; north=-36.45746; elevation=2228; name=Mt. Kosciusko` might be encoded in GeoSPARQL like this:

```
:mt-kosciusko
  a geo:Feature ;
  geo:hasGeometry [
    a geo:Geometry ;
    geo:hasSerialization "east=148.26218; north=-36.45746; elevation=2228;
name=Mt. Kosciusko"^^ex:dcmiPoint ;
  ] ;
.
```

[13] <https://www.dublincore.org/specifications/dublin-core/dcmi-box/>

[14] <https://www.dublincore.org/specifications/dublin-core/dcmi-point/>

E.10 The Provenance Ontology (PROV)

PROV Source: <https://www.w3.org/TR/prov-o/>

From GeoSPARQL's point of view, PROV is an "upper" ontology - one dealing with more abstract concepts - and only one of PROV's three main classes of object, **Entity**, **Activity** & **Agent** has direct relations to GeoSPARQL classes: **Entity**.

| From Element | Mapping relation | To Element | Notes |
|--------------------------|------------------------|----------------------|---|
| geo:SpatialObject | rdfs:subClassOf | prov:Entity | All SpatialObjects fit within PROV's Entity's definition: "An entity is a physical, digital, conceptual, or other kind of thing with some fixed aspects; entities may be real or imaginary." |
| geo:Feature | rdfs:subClassOf | prov:Location | A Location "...can be an identifiable geographic place (ISO 19112), but it can also be a non-geographic place such as a directory, row, or column" so seem to be wider in scope than GeoSPARQL's Feature although a Feature could indeed be something such as a "directory, row, or column" |
| prov:atLocation | - | - | The PROV property indicates a prov:Location , so perhaps a geo:Feature , but GeoSPARQL has no property to indicate a geo:Feature |

Derivative relations between GeoSPARQL objects could be modelled using PROV, for instance a BoundingBox may be indicated as having been derived from a Polygon like this:

```
:bounding-box-y prov:wasDerivedFrom :polygon-x .
```

E.11 WikiData

| From Element | Mapping relation | To Element | Notes |
|--------------|------------------------|------------------------------------|---|
| wdt:P625 | owl:equivalentProperty | geo:asWKT | The Wikidata description of this property labeled "coordinate location" note that "For Earth, please note that only WGS84 coordinating system is supported at the moment" but that is a system limit, not an ontological one |
| wdt:P3896 | owl:propertyChainAxiom | (geo:hasGeometry geo:asGeoJSON) | This Wikidata property labeled "geoshape" indicated GeoJSON geometry literal content for a Feature, but it allows information other than just Geometry in the GeoJSON whereas GeoSPARQL does not. |
| wdt:P3096 | owl:propertyChainAxiom | (geo:hasGeometry geo:asKML) | This Wikidata property labeled "KML File" links to a KML file which is related to the respective instance. This may not be the same representation as in GeoSPARQL, as GeoSPARQL KML literals only encode the geometry part of a KML. |

| | | | |
|--------------|---------------------|-------------------|---|
| wd:Q82794 | rdfs:subClassOf | geo:Feature | The Wikidata class is labeled "geographic region" and thus is a subclass of the more general geo:Feature . There are likely many other classes in Wikidata that could be interpreted as subclasses of geo:Feature |
| wd:Q618123 | owl:equivalentClass | geo:Feature | The Wikidata class is labeled "geographical feature" and thus corresponds to geo:Feature . |
| wd:Q25404640 | owl:equivalentClass | geo:SpatialObject | The Wikidata class is labeled "spatial object" and thus corresponds to geo:SpatialObject . |
| wdt:P150 | rdfs:subPropertyOf | geo:sfContains | The Wikidata property is labeled "contains administrative territorial entity" but also alternatively labeled "contains", "has districts" and others. There are likely many other specialised forms of geo:sfContains and geo:sfWithin in Wikidata |

| | | | |
|----------------|--------------------|----------------|---|
| geo:sfWithin | rdfs:subPropertyOf | wdt:P361 | The Wikidata property is labeled "part of" and is sometimes used to indicate Feature parthood. There are likely other parthood properties like this in Wikipedia that may also be used as superproperties of GeoSPARQL feature relations properties. The Wikidata inverse is wdt:Q65964571 "has part" |
| geo:sfContains | rdfs:subPropertyOf | wd:Q65964571 | The property labeled "has part" is the inverse of wdt:P361 (see above) |
| wdt:P131 | rdfs:subPropertyOf | geo:sfContains | The Wikidata property is labeled "located in the administrative territorial entity" and is essentially the inverse of wdt:150 (described above) |
| wdt:P706 | rdfs:subPropertyOf | geo:sfWithin | The Wikidata property is labeled "located in/on physical feature" and is indicated for use with a "(geo)physical feature" and not to be used for administrative features where wdt:131 (see above) should be |

| | | | |
|---------------------------|--|-----------------------------|--|
| wdt:P4688 | rdfs:subClassOf | geo:Feature | The Wikidata class is labeled "geomorphological unit" and is one of many Wikidata feature classes that could be expressed as a subclass of geo:Feature . More specailised geological unit examples are Q5107 "continent" and wdt:P4552 "mountain range". |
| wdt:P2046 | owl:equivalentProperty | geo:hasArea | The Wikidata property is labeled "area". It indicates a microformat - NUMBER + SPACE + ALLOWED_UNIT_LABEL - with a fixed set of ALLOWED_UNIT_LABELs to present values and units of measure. |

E.12 OpenStreetMap Ontologies

There are several approaches to make OpenStreetMap data accessible in the linked open data cloud.

E.12.1 LinkedGeoData

LinkedGeoData emerged from a research project linking

| From Element | Mapping relation | To Element | Notes |
|---------------|------------------------------|--------------------------|---|
| Any LGD Class | <code>rdfs:subClassOf</code> | <code>geo:Feature</code> | Any class defined in the LinkedGeoData ontology is a subclass of <code>geo:Feature</code> |

E.12.2 OpenStreetMap RDF (Sophox)

https://wiki.openstreetmap.org/wiki/Sophox#How_OSM_data_is_stored

| From Element | Mapping relation | To Element | Notes |
|----------------------------|-------------------------------------|----------------------------|--|
| <code>osmm:loc</code> | <code>owl:equivalentProperty</code> | <code>geo:asWKT</code> | The OpenStreetMap RDF property <code>osmm:loc</code> includes WKT literals which depending on the type of the subject instance describe an OSM node or the centroid of a way or OSM relation |
| <code>osmm:type 'n'</code> | <code>owl:equivalentClass</code> | <code>sf:Point</code> | The OpenStreetMap RDF property <code>osmm:type</code> with value 'n' describes an OSM Node which is equivalent to a <code>sf:Point</code> |
| <code>osmm:type 'w'</code> | <code>owl:equivalentClass</code> | <code>sf:LineString</code> | The OpenStreetMap RDF property <code>osmm:type</code> with value 'w' describes an OSM Way which is equivalent to a <code>sf:LineString</code> |

| | | | |
|----------------------------------|-------------------------------------|---|---|
| <code>osmm:type 'r'</code> | <code>owl:equivalentClass</code> | <code>sf:GeometryCollection</code> | The OpenStreetMap RDF property <code>osmm:type</code> with value <code>'r'</code> describes an OSM relation Way which is equivalent to a <code>sf:GeometryCollection</code> |
| <code>osmm:has</code> | <code>owl:equivalentProperty</code> | <code>geo:sfContains</code> , <code>geo:ehContains</code> , <code>geo:rcc8ntpp</code> | The OpenStreetMap RDF property <code>osmm:has</code> describes that a relation contains a way or that a way contains a node |
| <code>osmm:isClosed true</code> | <code>owl:equivalentClass</code> | <code>sf:Polygon</code> | The OpenStreetMap RDF property <code>osmm:isClosed</code> indicates whether a Way is closed, i.e. if it constitutes a Polygon |
| <code>osmm:isClosed false</code> | <code>owl:equivalentClass</code> | <code>sf:LineString</code> | The OpenStreetMap RDF property <code>osmm:isClosed</code> indicates whether a Way is closed, i.e. if it constitutes a Polygon |

E.12.3 Routable Tiles Ontology

<https://github.com/openplannerteam/routable-tiles-ontology>

| From Element | Mapping relation | To Element | Notes |
|---------------------------|----------------------------------|------------------------------------|---|
| <code>osm:Element</code> | <code>owl:equivalentClass</code> | <code>geo:Geometry</code> | The class <code>osm:Element</code> is equivalent to a <code>geo:Geometry</code> |
| <code>osm:Node</code> | <code>owl:equivalentClass</code> | <code>sf:Point</code> | The class <code>osm:Node</code> is equivalent to a <code>sf:Point</code> |
| <code>osm:Way</code> | <code>owl:equivalentClass</code> | <code>sf:LineString</code> | The class <code>osm:Way</code> is equivalent to a <code>sf:LineString</code> |
| <code>osm:Relation</code> | <code>owl:equivalentClass</code> | <code>sf:GeometryCollection</code> | The class <code>osm:Relation</code> is equivalent to a <code>sf:GeometryCollection</code> |

E.13 Ordnance Survey UK Spatial Ontology

Source: <http://www.ordnancesurvey.co.uk/legacy/ontologies/spatialrelations.owl>
<http://www.ordnancesurvey.co.uk/legacy/ontologies/geometry.owl>

| From Element | Mapping relation | To Element | Notes |
|---|-------------------------------------|---------------------------------|--|
| <code>spatialuk:contains</code> | <code>owl:equivalentProperty</code> | <code>geo:sfContains</code> | |
| <code>spatialuk:disjoint</code> | <code>owl:equivalentProperty</code> | <code>geo:sfDisjoint</code> | |
| <code>spatialuk:easting</code> | <code>owl:equivalentProperty</code> | - | Easting describes a latitude coordinate east of the national UK grid |
| <code>spatialuk>equals</code> | <code>owl:equivalentProperty</code> | <code>geo:sfEquals</code> | |
| <code>spatialuk:northing</code> | <code>owl:equivalentProperty</code> | - | Easting describes a longitude coordinate north of the national UK grid |
| <code>spatialuk:touches</code> | <code>owl:equivalentProperty</code> | <code>geo:sfTouches</code> | |
| <code>spatialuk:within</code> | <code>owl:equivalentProperty</code> | <code>geo:sfWithin</code> | |
| <code>spatialukgeom:AbstractGeometry</code> | <code>owl:equivalentProperty</code> | <code>geo:Geometry</code> | |
| <code>spatialukgeom:extent</code> | <code>owl:equivalentProperty</code> | <code>geo:hasBoundingBox</code> | |
| <code>spatialukgeom:asGML</code> | <code>owl:equivalentProperty</code> | <code>geo:asGML</code> | The properties are equivalent, but the range of <code>spatialukgeom:asGML</code> is more general: An <code>rdf:XMLLiteral</code> |

E.14 CIDOC CRM Geo

CRMGeo Source: https://www.cidoc-crm.org/crmgeo/sites/default/files/CRMgeo1_2.pdf

| From Element | Mapping relation | To Element | Notes |
|--|------------------------------|---------------------------|--|
| <code>cidoc:SP1_PhenomenalSpaceTimeVolume</code> | <code>rdfs:subClassOf</code> | <code>geo:Feature</code> | The CIDOC CRMgeo class <code>SP1_PhenomenalSpaceTimeVolume</code> is a subclass of <code>geo:Feature</code> as described in the CRMgeo 1.2 specification document. |
| <code>cidoc:SP2_PhenomenalPlace</code> | <code>rdfs:subClassOf</code> | <code>geo:Feature</code> | The CIDOC CRMgeo class <code>SP2_PhenomenalPlace</code> is a subclass of <code>geo:Feature</code> as described in the CRMgeo 1.2 specification document. |
| <code>cidoc:SP5_GeometricPlaceExpression</code> | <code>rdfs:subClassOf</code> | <code>geo:Geometry</code> | The CIDOC CRMgeo class <code>SP5_GeometricPlaceExpression</code> is a subclass of <code>geo:Geometry</code> as described in the CRMgeo 1.2 specification document. |
| <code>cidoc:SP6_DeclarativePlace</code> | <code>rdfs:subClassOf</code> | <code>geo:Geometry</code> | The CIDOC CRMgeo class <code>SP6_DeclarativePlace</code> is a subclass of <code>geo:Geometry</code> as described in the CRMgeo 1.2 specification document. |
| <code>cidoc:SP7_DeclarativePlace</code> | <code>rdfs:subClassOf</code> | <code>geo:Geometry</code> | The CIDOC CRMgeo class <code>SP7_DeclarativePlace</code> is a subclass of <code>geo:Geometry</code> as described in the CRMgeo 1.2 specification document. |

| | | | |
|---|------------------------------|---------------------------|--|
| <code>cidoc:SP10_DeclarativeTimeSpan</code> | <code>rdfs:subClassOf</code> | <code>geo:Geometry</code> | The CIDOC CRMgeo class <code>SP10_DeclarativeTimeSpan</code> is a subclass of <code>geo:Geometry</code> as described in the CRMgeo 1.2 specification document. |
| <code>cidoc:SP14_TimeExpression</code> | <code>rdfs:subClassOf</code> | <code>geo:Geometry</code> | The CIDOC CRMgeo class <code>SP14_TimeExpression</code> is a subclass of <code>geo:Geometry</code> as described in the CRMgeo 1.2 specification document. |
| <code>cidoc:SP15_Geometry</code> | <code>rdfs:subClassOf</code> | <code>geo:Geometry</code> | The CIDOC CRMgeo class <code>SP15_Geometry</code> is a subclass of <code>geo:Geometry</code> as described in the CRMgeo 1.2 specification document. |

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