GeoSPARQL 1.1: an almost decadal update to the most important geospatial LOD standard

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Abstract. The Open Geospatial Consortium published the GeoSPARQL
1.0 standard in 2012 containing multiple parts that define "SPARQL
extension functions", "RIF rules", "an RDF/OWL ontology for information
based on the General Feature Model" and supporting vocabularies, all
for Semantic Web spatial data.

In the 8+ years since its publication, GeoSPARQL has become the most
important spatial Semantic Web standard, as judged by references to it
in other Semantic Web standards and its wide use in Semantic Web data.

An update to the standard was proposed in 2019 to deliver GeoSPARQL
1.1 in 2021 with a charter to: handle outstanding change requests and
source new ones from the GeoSPARQL user community as well to "better
present" the standard, that is to better link all the standard's parts
and better document & exemplify elements. Expected updates included
possible alignments to other ontologies, possible handling of new spatial
referencing systems, new geometry representations, and new artifact
presentation.

In this paper, we will discuss the submitted change requests and resulting
updates to the standard. We will also discuss the theory behind updates
and our expectations for GeoSPARQL 1.1's use.

Keywords: GeoSPARQL · GeoSPARQL 1.1 · spatial · geospatial · Semantic
Web · RDF · OWL · OGC · Open Geospatial Consortuim · standard.

1   Introduction

The GeoSPARQL standard, first issues in 2021 by the Open Geospatial Consortium (OGC)[4] is one of, if not the most[5], used *Sematic Web* ontologies for representing spatial data.

The original GeoSPARQL release, which we refere to as GeoSPARQL 1.0, contained a *specification* document, a main "GeoSPARQL" ontology in an RDF file and a "Simple Features Vocabulary" ontology also in an RDF file. The "GeoSPARQL" ontology content, as well as lists of geospatial functions that could be performed on RDF data via SPARQL[6] queries was defined in the specification document, as were entailement rules and requirements & abstract tests for testing ontology data and function implementations. Within the last few years, the function lists from the spececification were extracted into a SKOS[7] vocabulary.

2   Motivation to update GeoSPARQL

Interest in updating GeoSPARQL had been captured[8] by the World Wide Web Consortium's (W3C) *Spatial Data On The Web Working Group* (SDWWG) when a large body of work was done on *Semantic Web* spatial data around in approximately 2015 - 2017, but no updates to GeoSPARQL were ultimately made by that Working Group.

Recently, 2019, the OGC reconstituted a *GeoSPARQL Standards Working Group* (SWG) to update GeoSPARQL. The general motivation for work within the area of GeoSPARQL, that of *Semantic Web* spatial data, and a series of fault fixes and proposed extensions to GeoSPARQL 1.0 are captured in an OGC White Paper [?]. Some, but not all, of the SDWWG's proposals are included in the White Paper with the different communities - W3C and OGC - naturally reflecting different desires.

The SWG's charter - it's final scope of work - is also published by the OGC [?] and this guides the SWG's activities. Specific actions of the SWG and their staging are explained through the use of a publicly-available online task tracking system within the SWG's working online code repository[9].

At a high-level, proposed updates to GeoSPARQL by both the SDWWG and the SWG may be categorised as:

- small geometry extensions, as predicted in GeoSPARQL 1.0

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[4] https://www.ogc.org

[5] It is hard to calculate use but references to GeoSPARQL in papers and other well-known standards, such as DCAT2 (https://www.w3.org/TR/vocab-dcat/) suggests this

[6] https://www.w3.org/TR/sparql11-query/

[7] https://www.w3.org/TR/skos-reference/

[8] https://www.w3.org/2015/spatial/wiki/Further_development_of_GeoSPARQL

[9] https://github.com/opengeospatial/ogc-geosparql/projects/1

– class extensions to cater for spatial information in RDF/OWL with more
   fidelity
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3   New features in GeoSPARQL 1.1

One of the first actions undertaken by the SWG was to link the GeoSPARQL
1.0 elements through a *profile* declaration, where a profile is a special type of
specification, as defined by *The Profiles Vocabulary*[?]. The specific motivation
for this was the SWG's recognition that GeoSPARQL 1.0 consisted of multiple
parts, not all of which were easy to discover and, as a result, some GeoSPARQL
users were unaware of some of the resources and some resources were accidentally
duplicated or partly re-implemented.

   The profile declaration will be published by the OGC as a stand-alone resource
sometime in mid-2021 along with some updated GeoSPARQL 1.0 resources.
Currently, all of the elements of GeoSPARQL 1.0, including the profile declaration,
can be found within the SWG's working online repository [10].

3.1   New geometry literals

GeoSPARQL 1.1 introduces three new literal types: A GeoJSON[?] literal, a
KML[?] literal, and a DGGS[?] WKT Literal.

Listing 1.1. GeoJSON literal example

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

Since the GeoJSON and KML formats are restricted to be represented in the
WGS84 coordinate system only, these restrictions also apply to GeoJSON and
KML literals. The DGGS WKT literal

3.2   Spatial aggregate functions

GeoSPARQL 1.1 includes new spatial aggregate functions, which allow for the
quick aggregation of different geometry types. While spatial aggregate functions
are the norm in many non-semantic geospatial databases such as POSTGIS or
Oracle Spatial, at the time of defining the GeoSPARQL 1.0 standard, aggregate
functions had not yet been introduced into the SPARQL standard since SPARQL
1.1 [?] was released about one year later. Spatial aggregate functions similar to
traditional aggregate functions such as AVG,MAX, or MIN allow to aggregate
results of geometry queries, e.g., to create the union out of a set of given
geometry literal results. While calculating these aggregates may also be possible
outside of the semantic database, the inclusion of the functions provides distinct
advantages:

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[10] https://github.com/opengeospatial/ogc-geosparql

1. No client-side library is needed to create an aggregated geometry result
2. Fewer and more appropriate results can be returned using a spatial aggregate function (e.g., a single union geometry vs. a set of geometries for which to create union externally)
3. Spatial aggregates from different SPARQL endpoints can easily be calculated using federated queries

GeoSPARQL 1.1 defines the aggregate functions *geosf:boundingCircle*, calculating a bounding circle around a set of geometry, *geosf:centroid* calculating the centroid of the set of geometries, *geosf:concatLines* concatenating a set of linestrings that overlap, *geosf:concaveHull* calculating the concave hull of a set of geometries and*geosf:union*, calculating the union of a set of geometreis, in addition to the *geosf:envelope* and *geosf:convexHull* functions already defined in the GeoSPARQL 1.0 standard. Since SPARQL 1.1 these fucntions were also usable as aggregate functions. Spatial aggregate function definitions are accompanied by the functions *geof:maxX*, *geof:maxY*, *geof:maxZ* and *geof:minX*, *geof:minY*, *geof:minZ* which allow to retrieve the minimum and maximum coordinates of a geometry respectively.

3.3   Extensions of the GeoSPARQL ontology

GeoSPARQL 1.1 extends the GeoSPARQL ontology by adding a new class geo:SpatialMeasure. This class represents a measurement such as a volume, length, or area associated with a measurement amount and a measurement unit. It acts as a range of three newly defined properties geo:hasArea, geo:hasLength, geo:hasVolume which make these attributes of a geometry better accessible using SPARQL. Finally, GeoSPARQL 1.1 adds the geo:inCRS property, which allows querying the coordinate reference system of a given geometry without the need to analyze geometry literal serializations. The property allows for the definition of a CRS as a URI. It paves the way for a future definition of coordinate reference systems fully in RDF as anticipated for GeoSPARQL 2.0.

> I created a graphic (geold_ontology.graphml) containing geo:SpatialObject, geo:Feature, geo:SpatialMeasure using the yEd Editor (https://www.yworks.com/products/yed) . If you find it useful we can extend it.

4   Modernizing the documentation of GeoSPARQL

4.1   Profile

5   Conclusions

5.1   Future Work

GeoSPARQL 1.2, GeoSPARQL 2.0?

- GeoSPARQL extension ontologies: CRS systems
- GeoSPARQL 1.2: More literals?
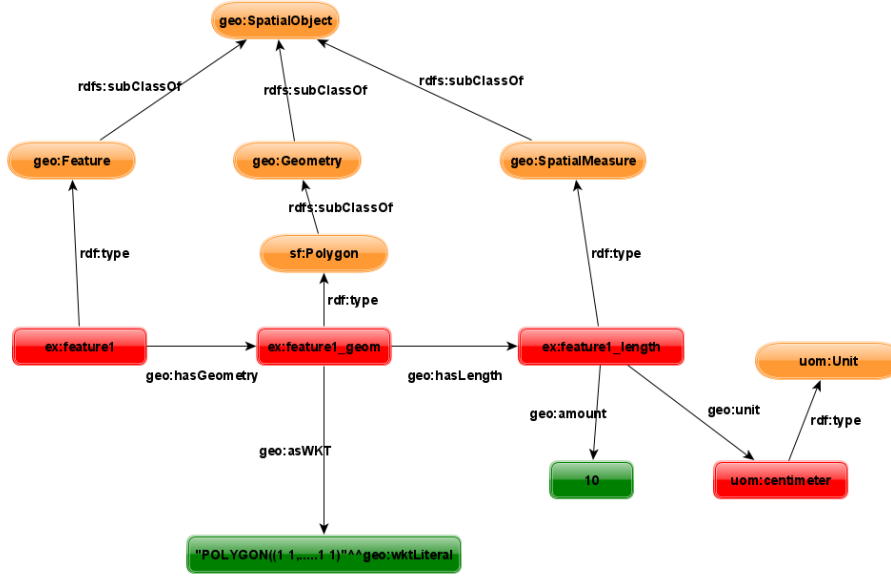- GeoSPARQL 2.0: Full featured support for 3D, simple features functions, coverages?

Fig. 1. GeoSPARQL 1.1 ontology including one example feature

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