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 sepecification 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 [1]. 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 [2] 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 one of the following:

- new geometry serializations
  - GeoJSON and other formats that have become popular since GeoSPARQL 1.0 's publication

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

[5] It's hard to calculate use but references to GeoSPARQL 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

* new ontology classes to cater for more nuanced spatial information
* more spatial functions
  – implementing functions well-known in non `Semantic Web` spatial systems
* scalar spatial properties
  – area, volume etc. alongside geometries
* better handling of Spatial (Coordinate) Reference Systems (SRS)
  – potentially allowing for automated coordinate serialization conversions
* Internet protocol-based selection of different geometries for features

Some of these propsed updates were predicted in GeoSPARQL 1.0 with the *Future Work* section listing several of the points above as expected or potential.

The SWG's *Charter*, anticipating that the more obvious updates such as new geometry serializations would certainly be implemented, listed the following areas of investigation that emerged from SWG proponent's discussions:

* a revision of the "upper ontology" structuring of GeoSPARQL
  – better/differently defining how GeoSPARQL's `Feature` and other classes relate to one another and to other fundamental concepts in ontology
* possible alignments to other ontologies, perhaps the *W3C Time Ontology in OWL*[5]
* catering for new and very different SRSes, such as Discrete Global Grid Systems (DGGS)

Specifically ruled out of scope was any investigation of property graphs. Recent (last several years) discussion in the OGC and elsewere about property graphs motivated a consideration of them, hoever the SWG proponents felt that while property graphs might be important for future *Semantic Web* spatial data systems, there was more than enough work scoped for initial SWG work (several revisions of the standard) to initially exclude this are of investigation.

After initial meetings, the SWG determined to make multiple releases of GeoSPARQL updates with different goals:

* **1.1**: extensions that are fully compatable with GeoSPARQL 1.0
* **1.2**: fully or mostly compatable extensions but which are larger additions to the standard's conceptual coverage
* **2.0**: a future GeoSPARQL that might be quite different and partly incompatable with GeoSPARQL 1.0

The reason for expecting a future, incompatable, GeoSPARQL 2.0 is that early SWG attendees thought spatio-temporal relations and fundamental ontology elements in GeoSPARQL either could or should be remodelled which might break the current, familiar, `Feature/Geometry` class relations. Details of these potential changes haven't been fully expounded, at the time of this paper, however initial SWG attendees' intuition is that a future GeoSPARQL 2.0 might generalise spatial concepts and move away from only, or primarily, *geo*spatial, or perhaps focus not just on `Feature/Geometry` relations but look to generalised mechanisms for describing dimensions of features of which *geometry* is one of many (and perhaps) *temporality* too).

An additional area of updates to GeoSPARQL that was not forseen by GeoSPARQL 1.0, the SDWWG or the initial proponants of the SWG but which was included by the early SWG attendees in GeosPARQL 1.1 and is now present in the SWG's working repository was that of new modes of standard presentation. The motivation for this was conceptual work within the W3C and the OGC to do with how multi-part standards might link their parts and declare dependencies. This resulted in the profile declaration work, explained in the next section.

3 Updates in GeoSPARQL 1.1

So far (as of June, 2020) the GeoSPARQL SWG has triarged changed requests into GeoSPARQL 1.1, 1.2 $ 2.0 releases and has addressed many 1.1 requests. Here we report only on those 1.1 requests. This section describes some of the areas updated in GeoSAPRQL 1.1 and the following section foreshadows likely 1.2 and 2.0 updates.

3.1 Profile Declaration

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*[3]. 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. Profile declarations of this sort are anticipated, by the OGC, as being the *best practice* way for it to deliver multi-part standards.

The profile declaration for GeosPARQL 1.0 will be published by the OGC as a stand-alone resource sometime in early 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]. The profile declaration for GeosPARQL 1.1 will be published at the same time as all, or most, of the 1.1 releases' updated resources, currently expected in mid-2021.

3.2 New geometry literals

GeoSPARQL 1.1 introduces three new litergeometry serializations:

1. GeoJSON (Geo- JavaScript Object Notation)[4]
2. KML (Keyhole Markup Language)[6]
3. DGGS (Discrete Global Grid System)[7]

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

The first two of these are "obvious" in the sence that that they have been expected/requested by the SDWWG and many users of GeoSPARQL for a long time, due to those format's popularity. an example of a GeoJSON geometry serialization is given below.

Listing 1.1. GeoJSON geometry serialization 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 SRS only, these restrictions also apply to GeoJSON and KML literals. The DGGS WKT literal

The third new serialization format is more forward-looking in that it is not dirven by user demand but by predected demand. DGGS does not have a single, concrete format standard as the others do, not is it ever likely to - different DGGSes will likely implement very different data formats - so GeoSAPRQL 1.1 makes generalized provisions for DGGS serializations but presents no detailed requirements for them, only stating that the specific DGGS must be identified.

3.3 New spatial 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 [8] 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:

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.

3.4 Ontology extensions

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:inSRS property, which allows querying the SRS of a given geometry without the need to analyze geometry literal serializations. The property allows for the definition of a SRS as a URI. It paves the way for a future definition of SRS fully in RDF as anticipated for GeoSPARQL 2.0.

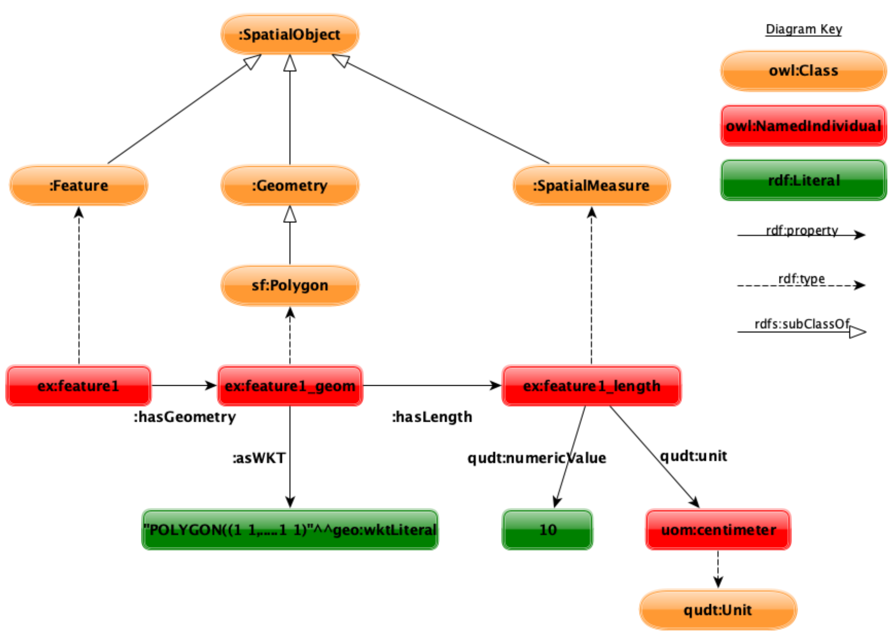

Fig. 1. GeoSPARQL 1.1 ontology including one example feature

4 Modernizing the documentation of GeoSPARQL

4.1 Profile

5 Conclusions

5.1 Future Work

GeoSPARQL 1.2, GeoSPARQL 2.0?

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

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