

Geospatial Ontology Trade Study

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Abstract. This short paper summarizes a survey of ontologies relevant to geospatial intelligence. 45 geospatial and temporal ontologies, in 11 categories, were assessed against 3 use cases: annotation, qualitative reasoning, and information integration. Specific recommendations and more general conclusions are provided. The paper presents an illustration of a feature with several different ontology representations.

Keywords: ontology, geospatial intelligence, Semantic Web, OWL, temporal

Introduction

An ontology is a formal, explicit, shared conceptualization of a domain. As such, it defines the concepts and vocabulary used within a community of interest. The formal, machine-understandable representation allows use of the ontology to support logical inference. The Semantic Web has motivated increased development and use of ontologies, while at the same time driving the need for common ontologies.

A trade study conducted a broad survey of 45 ontologies that apply to the spatial, event, and temporal granularity concepts [3]. The study has reviewed thousands of classes and properties in order to find the characteristics that make these ontologies best suited to the geospatial intelligence community for uses in annotation, qualitative reasoning and interoperability. The study has made several strategic recommendations to further the development of semantic technology and the application of these ontologies.

To focus discussion and applicability, the study considered three primary use cases motivating the development and selection of geospatial and related ontologies.

- **Annotation:** using classes and properties to represent relevant characteristics of objects
- **Qualitative Reasoning:** reasoning about spatiotemporal relationships between objects (e.g. containedWithin, connectedTo, During)
- **Information Integration:** facilitate interoperability by mapping other data models to/from a common encompassing reference ontology

The study used seven categories of Geospatial Ontologies¹ from the W3C Geospatial Incubator Group with four additional categories to fully represent the range of geospatial and temporal data:

¹ <http://www.w3.org/2005/Incubator/geo/>

1. Geospatial Feature Ontology
2. Feature Type Ontology
3. Spatial Relationship Ontology
4. Toponym (Place name) Ontology
5. Coordinate Reference / Spatial Grid Ontology
6. Geospatial Metadata Ontology
7. (Geospatial) Web Services Ontology
8. Geometric Ontology
9. Coverage Ontology
10. Geopolitical Ontology
11. Temporal Ontology

Ontologies Surveyed

The study included the following ontologies:

- Basic Formal Ontology
- DOLCE
- Cyc (Geodesy, Linear Object, Map Projection, Open Geospatial Consortium, Surface Geometry, Temporal Predicates, Time Interval, Terrain, and Topology domains)
- FGDC Content Standard for Digital Geospatial Metadata
- ISO Geographic Information (Conceptual Schema Language/19103, Spatial/19107, Temporal/19108, Application Schema/19109, Feature Cataloguing/19110, Spatial Reference-coordinates/19111, Geographic Identifier/19112, Metadata/19115, Coverage/19123)
- SOUPA (RCC, Geomeasurement, Event, Time)
- SUMO (SUMO, MILO, Geography)
- Enterprise Conceptual Data Model
- NSG Application Schema
- georSS (BasicGeo, NEOGEO)
- Geography Markup Language (ISO 19136)
- Keyhole Markup Language
- geonames.org
- MINDSWAP (geoCoordinateSystems, geoFeatures, geoRelations)
- SWEET (Space, Time)
- S-57 (maritime domain)
- OWL-Time
- RDF Calendar

Representations of most of the ontologies were available in the W3C OWL Web Ontology Language [2], which was the focus of the study. Some were originally

developed using other representations and then converted to OWL, sometimes with some loss of expressivity. Several had not yet been represented in OWL.

Conclusions

The principal recommendations of the study were:

- There are a number of acceptable OWL ontologies and related representations available that can be re-used and extended for a domain.
- Update, formalize and control ontologies in a best practice document aligned with existing standards.
- Create an ontology library for the ISO Geographic Information technical committee specifications and encourage the U.S. to submit these ontologies to ISO for approval.
- Use the National System for Geospatial Intelligence (NSG) Application Schema as the basis of a standard feature type ontology.
- Representatives from the geospatial intelligence community should participate in the new ISO Technical Committee 211 project 19150 to promote spatial upper ontologies.

The study also recommends the following guidelines for reusing geospatial ontologies:

- Use OWL for ontology definition.
- Use the simplest OWL representations that meet application needs.
- Geospatial Ontologies should be based upon standards consistent with the NSG Architecture and with the GEOINT Standards listed in the Defense Information Standards Registry (DISR), which are also contained in the NSG Architecture Compliance.

For the Geospatial Intelligence user, a recommended ontology/set of ontologies for each of the ontology categories and use cases described is shown in Table 1. Each row and column also includes the number of applicable ontologies. For each category or use case, these criteria were used: “Fully” means that the concepts in the ontology directly apply without modification; “Partially” means that some of the concepts apply, but it is not the primary intent of the ontology or requires modification; “Indirectly” means that while not being directly applicable, the ontology contributes towards application. Several categories are marked “Not Applicable” because the ontology category was not intended for the use case (e.g. Qualitative Reasoning). The rationale for each category recommendation is contained in the trade study report [3].

Ontology Category	Recommended Ontology per Use Case		
	Annotation (15 fully, 12 partially, 5 indirectly)	Qualitative Reasoning (7 fully, 8 partially, 2 indirectly)	Information Integration (8 fully, 7 partially, 21 indirectly)
1. Geospatial Feature (7 fully, 6 partially)	GeoRSS (Simple or GML)	Not applicable	GML
2. Feature Type (6 fully, 2 partially)	NSG FC / NAS 1.8 (in OWL)	Not applicable	NSG FC / NAS 1.8 (in OWL)
3. Spatial Relationship (3 fully, 6 partially)	SOUPA rcc	SOUPA rcc	SOUPA rcc
4. Toponym (1 fully, 4 partially)	ISO 19112	Not applicable	ISO 19112
5. Coordinate Reference (4 fully, 2 partially)	ISO 19111, Cyc Map Projection	Not applicable	ISO 19111
6. Geospatial Metadata (2 fully, 3 partially)	ISO 19115	Not applicable	ISO 19115
7. Web Service (0 fully, 2 partially)	Not evaluated	Not evaluated	Not evaluated
8. Geometric (4 fully, 4 partially)	ISO 19107	SOUPA rcc	ISO 19107
9. Coverage (1 fully, 4 partially)	None available	Not applicable	None available
10. Geopolitical (2 fully, 3 partially)	None recommended	Not applicable	None recommended
11. Temporal (6 fully, 4 partially)	XML datatypes in OWL, OWL-Time	OWL-Time	OWL-Time

Table 1: Recommended Spatiotemporal Ontologies

In addition to these recommendations, these follow-up actions were recommended.

- Existing ontologies that have unique and useful concepts, such as Cyc, MINDSWAP, and SUMO, should be linked to NSG ontologies and augmented with NGA specific domain concepts from the ECDM and GSIP.
- Perform a metrics evaluation of the quality of the selected ontologies similar to the assessment performed by Burton-Jones on the DAML ontology library [1]. This quality assessment developed measurements of an ontology's syntax, richness, interpretability, clarity, comprehensibility and relevance.
- Given the active interest in service oriented architectures, the use of ontologies to describe services (such as OWL-S and SAWSDL) is an active area of research and commercial development. An evaluation of ontologies to represent web services is recommended for a future study.

The Spatial Ontology Community of Practice (SOCoP) of the US Federal CIO Council provides a good forum for exposing and coordinating geospatial ontologies. As intelligence agencies employ semantic technology, interoperability should be considered

from the outset because semantic queries are not inherently interoperable when performed across domains. It is in the best interest of the Intelligence Community to act on these recommendations and guidelines to provide interoperable and mature semantic technology.

References

[1] Burton-Jones, A., Storey, V., Sugumaran, V., Ahluwalia, P. “A semiotic metrics suite for assessing the quality of ontologies.” *Data & Knowledge Engineering* 55 (2005) 84-102.

[2] M. Dean and G. Schreiber, eds. OWL Web Ontology Language Reference. W3C Recommendation 10 February 2004. <http://www.w3.org/TR/2004/REC-owl-ref-20040210/>

[3] Ressler, J., Dean, M. and Kolas, D., “Geospatial Ontology Trade Study”, http://projects.semwebcentral.org/docman/?group_id=84, June 2007..

Appendix: Illustration of Feature Ontology

To ground the analysis and allow comparisons across ontologies, the study included annotations for a specific feature: The Pentagon in Washington, D.C., which is in the shape of a five-sided polygon as illustrated in Figure 1.



Figure 1: Pentagon Feature (GoogleEarth © Google)

The representation of The Pentagon feature in GeoRSS Simple is as follows:

```
<rdf:Description>
  <georss:featurename>Pentagon</georss:featurename>
  <georss:polygon>
    -77.05795370823761 38.87258672915797
    -77.05847549720639 38.87005708744568
    -77.0555999760046 38.86886750371786
    -77.05326581781736 38.87064560343153
    -77.05465594662488 38.87292421787603
    -77.05795370823761 38.87258672915797
  </georss:polygon>
</rdf:Description>
```

GeoRSS GML can encapsulate the GML representation of the feature:

```
<gml:FeatureCollection
  xmlns:gml="http://www.opengis.net/gml"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.safe.com/gml/fme
pentagon3.xsd">
  <gml:boundedBy>
    <gml:Envelope srsName="EPSG:4326" srsDimension="2">
      <gml:lowerCorner>-77.0584754972064
38.8688675037179</gml:lowerCorner>
      <gml:upperCorner>-77.0532658178174
```

```

38.872924217876</gml:upperCorner>
  </gml:Envelope>
</gml:boundedBy>
<gml:featureMember>
  <gml:surfaceProperty>
    <gml:Surface srsName="EPSG:4326" srsDimension="2">
      <gml:patches>
        <gml:PolygonPatch>
          <gml:exterior>
            <gml:LinearRing>
              <gml:posList>
                -77.0579537082376 38.872586729158
                -77.0584754972064 38.8700570874457
                -77.0555999760046 38.8688675037179
                -77.0532658178174 38.8706456034315
                -77.0546559466249 38.872924217876
                -77.0579537082376 38.872586729158
              </gml:posList>
            </gml:LinearRing>
          </gml:exterior>
        </gml:PolygonPatch>
      </gml:patches>
    </gml:Surface>
  </gml:surfaceProperty>
</gml:featureMember>
</gml:FeatureCollection>

```

The representation of the sample Pentagon feature in KML is as follows:

```

<Placemark>
  <name>The Pentagon</name>
  <styleUrl>#msn_ylw-pushpin</styleUrl>
  <Polygon>
    <tessellate>1</tessellate>
    <outerBoundaryIs>
      <LinearRing>
        <coordinates>
          -77.05795370823761,38.87258672915797,0
          -77.05847549720639,38.87005708744568,0
          -77.0555999760046,38.86886750371786,0
          -77.05326581781736,38.87064560343153,0
          -77.05465594662488,38.87292421787603,0
          -77.05795370823761,38.87258672915797,0
        </coordinates>
      </LinearRing>
    </outerBoundaryIs>
  </Polygon>
</Placemark>

```

Geonames.org returns the following information for The Pentagon:

```
<Feature rdf:about="http://sws.geonames.org/4778469/">
  <name>Pentagon</name>
  ...
  <alternateName xml:lang="fr">Pentagone</alternateName>
  ...
  <featureClass rdf:resource="http://www.geonames.org/ontology#S"/>
  <featureCode rdf:resource="http://www.geonames.org/ontology#S.BLDG"/>
  <inCountry rdf:resource="http://www.geonames.org/countries/#US"/>
  <wgs84_pos:lat>38.8709455</wgs84_pos:lat>
  <wgs84_pos:long>-77.0552551</wgs84_pos:long>
  <parentFeature rdf:resource="http://sws.geonames.org/4744725"/>
  <nearbyFeatures
    rdf:resource="http://sws.geonames.org/4778469/nearby.rdf"/>
  <locationMap>http://www.geonames.org/4778469/pentagon.html</locationMap>
  <wikipediaArticle
    rdf:resource="http://de.wikipedia.org/wiki/Pentagon"/>
</Feature>
```

The representation of the Pentagon example using SWEET is as follows:

```
<material_thing:Building>
  <space:hasBoundary>
    <numerics:Polygon>
      <numerics:hasVertices>
        <numerics:Point>
          <numerics:hasCoordinates>
            <space:GeographicalCoordinates>
              <rdf:_1>
                <space:Longitude>
                  <numerics:hasValue>77.05795370823761</numerics:hasValue>
                </space:Longitude>
              </rdf:_1>
              <rdf:_2>
                <space:Latitude>
                  <numerics:hasValue>38.87258672915797</numerics:hasValue>
                </space:Latitude>
              </rdf:_2>
            </space:GeographicalCoordinates>
          </numerics:hasCoordinates>
        </numerics:Point>
      </numerics:hasVertices>
      <!-- ... -->
    </numerics:Polygon>
  </space:hasBoundary>
</material_thing:Building>
```