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An Introduction to Linked Geospatial Data

December 22, 2025

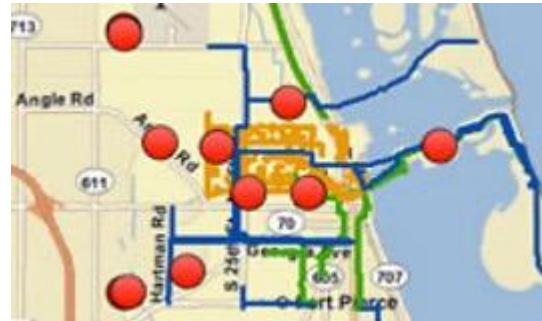
Outline

- Examples of geospatial information
- Geospatial knowledge graphs
- GeoSPARQL
- Tutorial for project 3

Examples of geospatial information

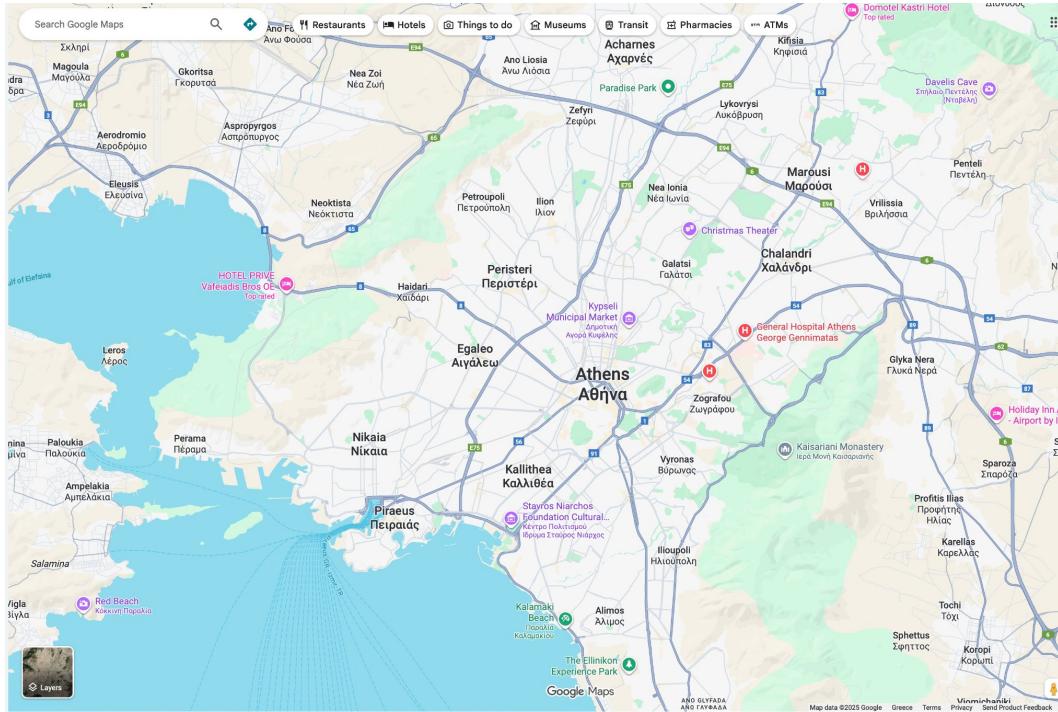
Why Geospatial Information?

- **Geospatial**, and in general **geographical**, information is very important in reality: everything that happens, happens somewhere (**location**).
- **Decision making can be substantially improved** if we know where things take place.



Geospatial data on the Web

Google Maps



Open Government Data

data.gov.uk | Find open data

Publish your data Documentation Support

BETA

Find open data

Find data published by central government, local authorities and public bodies to help you build products and services

Search data.gov.uk



Business and economy

Small businesses, industry, imports, exports and trade

Crime and justice

Courts, police, prison, offenders, borders and immigration

Defence

Armed forces, health and safety, search and rescue

Education

Students, training, qualifications and the National Curriculum

Environment

Weather, flooding, rivers, air quality, geology and agriculture

Government

Staff numbers and pay, local councillors and department business plans

Government spending

Includes all payments by government departments over £25,000

Health

Includes smoking, drugs, alcohol, medicine performance and hospitals

Mapping

Addresses, boundaries, land ownership, aerial photographs, seabed and land terrain

Society

Employment, benefits, household finances, poverty and population

Towns and cities

Includes housing, urban planning, leisure, waste and energy, consumption

Transport

Airports, roads, freight, electric vehicles, parking, buses and footpaths

Digital service performance

Cost, usage, completion rate, digital take-up, satisfaction

Government reference data

Trusted data that is referenced and shared across government



data.gov.gr

Ελληνικά | English

Επικοινωνία

Εισόδος χρηστών

Αρχική Αναζήτηση Δεδομένων Νομοθετικό Πλαίσιο Αποφάσεις

Βρείτε ανοικτά δεδομένα

Αναζητήστε δεδομένα δημόσιου ευεργετικού από την κεντρική διοικηση, οργανισμούς τοπικής αυτοδιοίκησης και άλλες υπηρεσίες

Αναζήτηση στο data.gov.gr



Θεματικές Ενότητες Δεδομένων

10 θεματικές ενότητες με 84 σειρές δεδομένων.

Δημοφιλέστερα Σύνολα Δεδομένων

Προχειρίς Παραβάσεις

Βεβαωμένες παραβάσεις ανά κατηγορία

Αριθμός Μαθητών ανά Σχολείο

Αριθμός μαθητών ανά σχολείο και φύλο

Απολύτη Αριθμός Διοίκησης

Η εφαρμογή «Μέτρηση Ιανουάριος των πολιτών από την παροχή δημόσιων υπηρεσιών» (xwlogos.yyes.gov.gr) δίνει τη δυνατότητα στους πολίτες να αισιοδούν τις δημόσιες υπηρεσίες που χρησιμοποιούσαν, συμβάλλοντας στην

Τελευταία νέα

Εφαρμόστε τις ιδέες σας σχετικά με το μέλλον της νομοθεσίας της ΕΕ για τα δεδομένα

Η Ευρωπαϊκή Επιτροπή, σε συνεργασία με εβεδικευμένους φορείς και εθνικούς εμπειρογνόμους, αξιολογεί τρεις σημαντικές νομοθετικές πράξεις της ΕΕ για τα δεδομένα, συμπεριλαμβανομένης της οδηγίας για τα ανοικτά δεδομένα, και καλεί τους πολίτες να συμμετάσχουν σε σχετικές δράσεις. Οι δράσεις αυτές εστιάζουν στην επαναχρησιμοποίηση δημόσιων δεδομένων, τον αντίκτυπο στην κοινωνία και την οικονομία, καθώς και στα εμπόδια που ενδέχεται να υπάρχουν.

Οικονομία και Εμπόριο

Οικονομία, εμπόριο, βιομηχανία, εισαγωγές, εξαγωγές



Δημόσια Τάξη και Δικαιοσύνη

Δικαστήρια, αστυνομία, φυλακές, ειγκλήματα, σύνορα και μετανάστευση



Εκπαίδευση

Μαθητές, φοιτητές, πανεπιστήμια, καθηγητές και βαθμολογίες



OpenStreetMap

OpenStreetMap Edit

History Export GPS Traces User Diaries Communities Copyright Help About

Log In Sign Up

Search Where Is this?  

Welcome to OpenStreetMap!

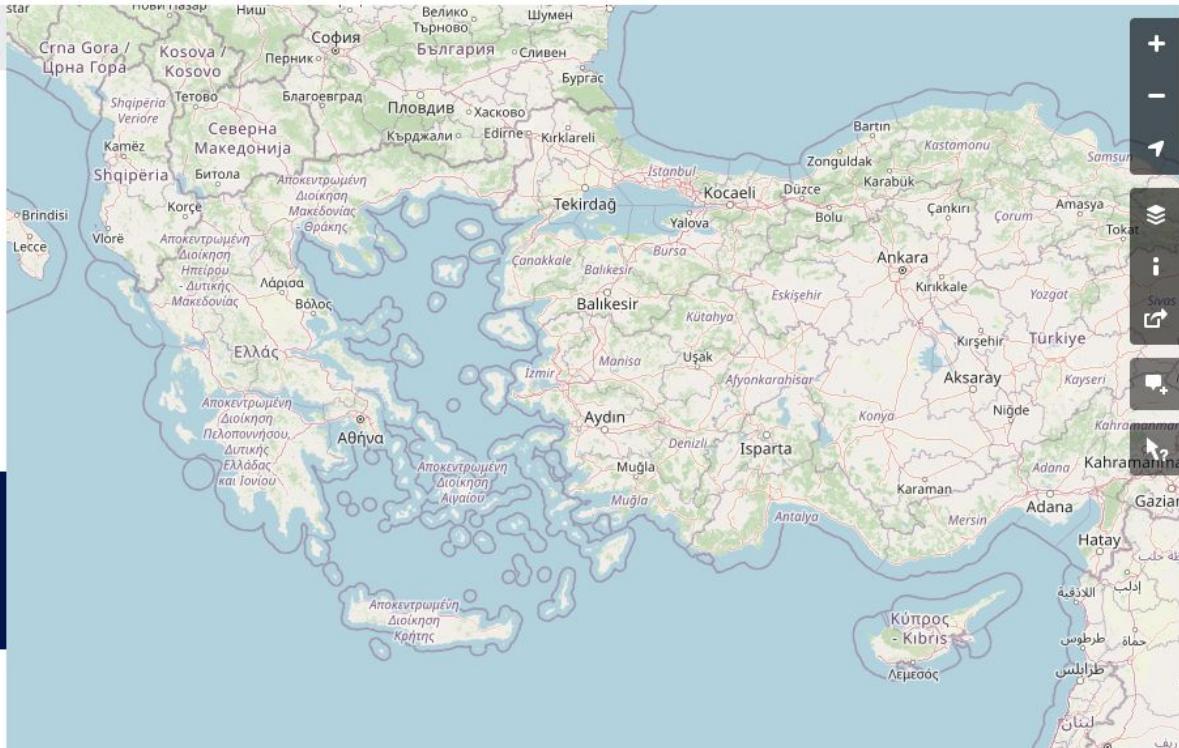
OpenStreetMap is a map of the world, created by people like you and free to use under an open license.

Hosting is supported by [Fastly](#), [OSMF](#) corporate members, and other partners.

[Learn More](#) [Start Mapping](#)

 State of the Map Europe

Two full days of talks, workshops, panels, and conversations about



Satellite image of Athens



Satellite image monitoring of wildfires



Earth Observation Programmes



Copernicus programme

<https://browser.dataspace.copernicus.eu/>

The screenshot shows the Copernicus Browser interface. On the left, a sidebar displays a list of search results for Sentinel-2 MSI imagery of Athens, Greece, on December 19, 2025. Each result includes a thumbnail, the file name, mission, instrument, size, and sensing time. The main area is a detailed satellite map of the Athens region, with the city center and surrounding areas like Piraeus and Chalandri clearly visible. The map includes various labels for neighborhoods and landmarks. On the right side of the map, there is a vertical toolbar with various icons for interacting with the map, such as zoom, pan, and layer selection. The bottom of the interface features the Copernicus logo and links to About and Support.

File Name	Mission	Instrument	Size	Sensing Time
S2A_MSIL1C_20251219T202601_N0511_R014_T34SGH_20251219T204534.SAFE	SENTINEL-2	MSI	5MB	2025-12-19T20:26:01.024000Z
S2A_MSIL1C_20251219T202601_N0511_R014_T35SKC_20251219T204534.SAFE	SENTINEL-2	MSI	6MB	2025-12-19T20:26:01.024000Z
S2A_MSIL1C_20251219T202601_N0511_R014_T34SFG_20251219T204534.SAFE	SENTINEL-2	MSI	5MB	2025-12-19T20:26:01.024000Z
S2A_MSIL1C_20251219T202601_N0511_R014_T34SGG_20251219T204534.SAFE	SENTINEL-2	MSI	4MB	2025-12-19T20:26:01.024000Z
S2A_MSIL1C_20251219T202601_N0511_R014_T34SFH_20251219T204534.SAFE	SENTINEL-2	MSI	6MB	2025-12-19T20:26:01.024000Z

Geospatial knowledge graphs

Geospatial information

- **Qualitative**
 - Cardinal direction relations (e.g., north of)
 - Topological relations (e.g., within, contains, overlaps, borders etc.)
 - Distance relations (e.g., near, far)
- **Quantitative**
 - Points
 - Lines
 - Polygons
 - More complex geometries
- **Geospatial knowledge graphs** are knowledge graphs representing not just **thematic** (e.g., “Tokyo is the capital of Japan” or “Nara has a population of 367,353 people”) but also **geospatial** information of the above kinds.



Geospatial knowledge graphs

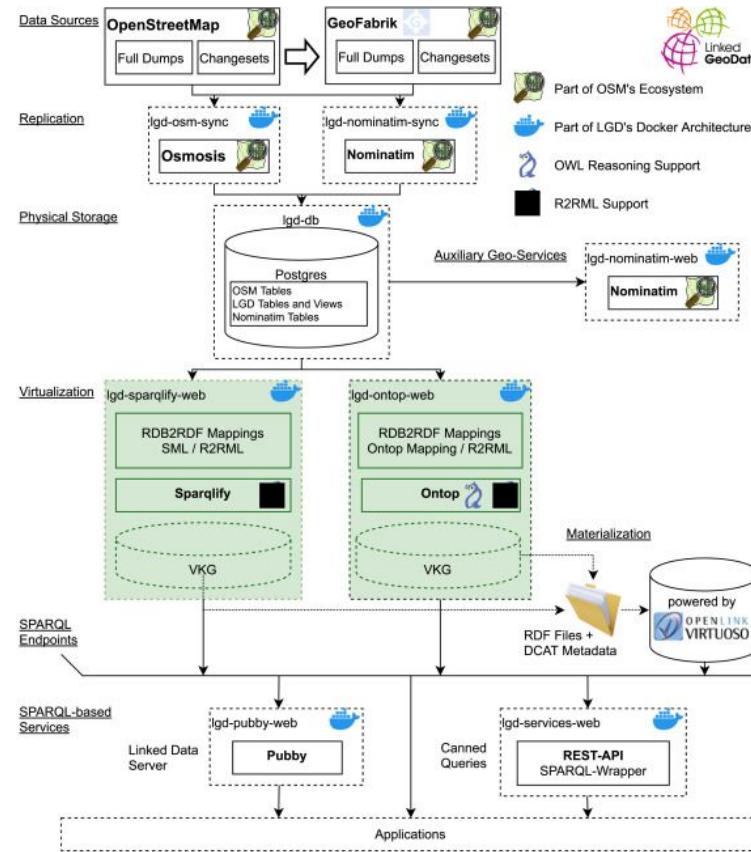
- **LinkedGeoData** was the first effort to add a spatial dimension to the Semantic Web. It made OpenStreetMap data available as RDF triples according to the Linked Data principles. In addition, it interlinked this data with other datasets in the Linked Open Data initiative.



Claus Stadler et al. *LinkedGeoData: A Core for a Web of Spatial Open Data*. Semantic Web Journal, 2012.

Linfang Ding et al. *Towards the next generation of the LinkedGeoData project using virtual knowledge graphs*. J. Web Semantics, 2021.

LinkedGeoData using Virtual Knowledge Graphs



Geospatial Knowledge Graphs

- **DBpedia** (lat/long coordinates, some cardinal directions, some topological relations implicitly)

About: Athens

An Entity of Type: [Capital city](#), from Named Graph: [http://dbpedia.org](#), within Data Space: [dbpedia.org](#)

Athens (/'æθənз/ ATH-inz; Greek: Αθήνα, romanized: Athína [a'θina]; Ancient Greek: Ἀθῆναι, romanized: Athēnai (pl) [at̪e̪nai]) is both the capital and largest city of Greece. With a population close to four million, it is also the seventh largest city in the European Union. Athens dominates and is the capital of the Attica region and is one of the world's oldest cities, with its recorded history spanning over 3,400 years and its earliest human presence beginning somewhere between the 11th and 7th millennia BC.

Property Value

dbo:PopulatedPlace/areaMetro	• 2928.717
dbo:PopulatedPlace/areaTotal	• 38.964

www.w3.org/2003/01/geo/wgs84_pos#long



About: Athens

geo:geometry • POINT(23.728055953979 37.98416519165)

geo:lat • 37.984165 (xsd:float)

geo:long • 23.728056 (xsd:float)

skos:exactMatch • [http://globalwordnet.org/ili/183036](#)

prov:wasDerivedFrom • [wikipedia-en:Athens?oldid=1124837889&ns=0](#)

foaf:depiction • [wiki-commons:Special:FilePath/10,000-meter final during the 2004 Olympics.jpg](#)
• [wiki-commons:Special:FilePath/20070523-4124-NERATZ/IOTISA.jpg](#)
• [wiki-commons:Special:FilePath/2009-02-19_Yachthafen_Glyfada_03.jpg](#)
• [wiki-commons:Special:FilePath/20090801_athina04.jpg](#)
• [wiki-commons:Special:FilePath/2012-02-29_12-06-25_Greece_Athina_Spira.jpg](#)
• [wiki-commons:Special:FilePath/20140407_athenes44.jpg](#)

Number of geoentities in DBpedia

In the English version of DBpedia, **1.53 million entities** have geographic coordinates (latitude and longitude).

Note: Calculated by Kostas and Gemini 2.5 Pro

This data is extracted from Wikipedia infoboxes and represents a wide range of geographically located entities, including:

- **Populated places:** Cities, towns, and villages.
- **Other locations:** Mountains, rivers, lakes, and other natural features.
- **Buildings and structures:** Famous landmarks, museums, and stadiums.

Geospatial Knowledge Graphs

- **Wikidata** (same as DBpedia but also geoshapes). Geoshapes encode complex geometries e.g., multipolygons.

Greece - Wikidata

wikidata.org/wiki/Q41

coordinates of westernmost point



39°41'30.5"N, 20°0'30.2"E

0 references

geoshape

Data:Greece.map

0 references

Data:Greece.map - Wikimedia Commons

commons.wikimedia.org/wiki/Data:Greece.map

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Data:Greece.map

From Wikimedia Commons, the free media repository

Greece



Number of geoentities in Wikidata

As of the latest data from Wikidata's SPARQL endpoint, the total number of geoentities is **12,968,093**.

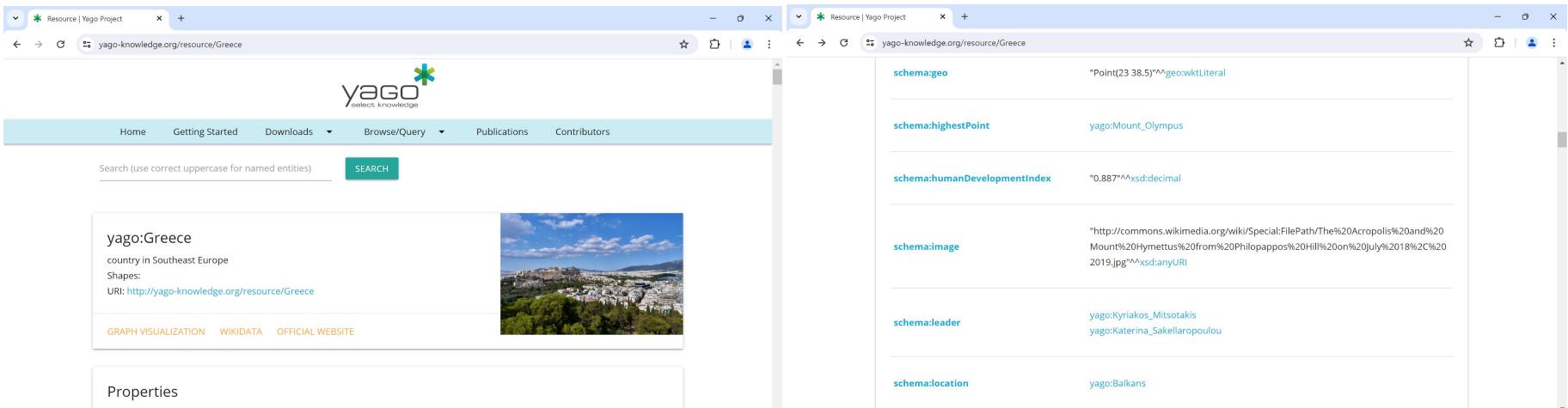
This total is a combination of two types of geospatial data:

- Entities with coordinate locations: **12,877,759**
- Entities with geoshapes: **90,334**

Note: Calculated by Gemini 2.5 Pro.

Geospatial Knowledge Graphs

- **YAGO2** (geoentities from Wikipedia and GeoNames, lat/long coordinates only, some topological relations implicitly)



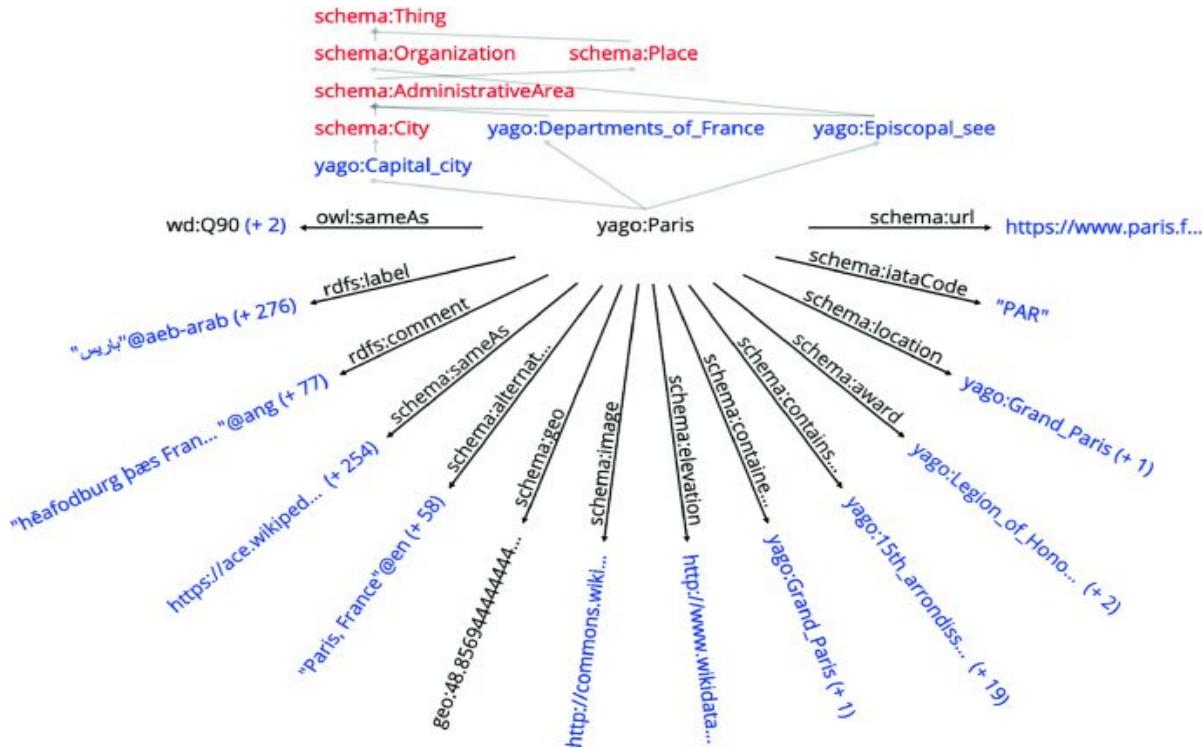
The image shows two browser windows side-by-side. The left window is the YAGO Project homepage, featuring a search bar, navigation links (Home, Getting Started, Downloads, Browse/Query, Publications, Contributors), and a search result for 'yago:Greece'. The result includes a photo of the Acropolis in Athens and links to Graph Visualization, Wikidata, and the Official Website. The right window is a detailed view of the 'Resource' page for Greece, showing its properties in a table format. The properties listed are:

Property	Value
schema:geo	"Point(23 38.5)"^^geo:wktLiteral
schema:highestPoint	yago:Mount_Olympus
schema:humanDevelopmentIndex	"0.887"^^xsd:decimal
schema:image	"http://commons.wikimedia.org/wiki/Special:FilePath/The%20Acropolis%20and%20Mount%20Hymettus%20from%20Philopappos%20hill%20on%20July%2018%2C%202019.jpg"^^xsd:anyURI
schema:leader	yago:Kyriakos_Mitsotakis yago:Katerina_Sakellaropoulou
schema:location	yago:Balkans

10 million geoentities

Hoffart et al. *YAGO2: A spatially and temporally enhanced knowledge base from Wikipedia*. Artif. Intell. 194: 28-61 (2013)

An Example from YAGO4.5 (<https://yago-knowledge.org/>)



Geospatial information in [schema.org](#)

The property **geo** can be used to encode geospatial information in [schema.org](#).

Property `geo` is expected to be used on type `Place` or `Event` and its values can be of types `GeoCoordinates` or `GeoShape`.

An instance of `GeoCoordinates` can be described with various properties including **latitude** and **longitude**.

Example in JSON-LD

```
<script type="application/ld+json">
{
  "@context": "https://schema.org",
  "@type": "Place",
  "geo": {
    "@type": "GeoCoordinates",
    "latitude": "40.75",
    "longitude": "-73.98"
  },
  "name": "Empire State Building"
}
</script>
```

Geospatial information in [schema.org](#)

An instance of `GeoShape` can be described with various properties including `line`, `box` and `polygon`.

A more specific type is `GeoCircle`.

YAGO 4.5

YAGO is now in version 4.5. So far it has not supported more complex geometries than coordinates.

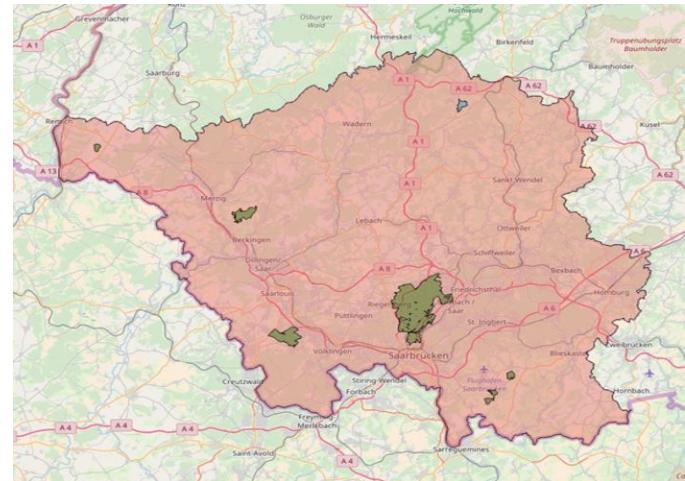


Geospatial Knowledge Graphs

- **YAGO2geo** (it adds to YAGO2 more complex geometries from administrative divisions of four countries and some OpenStreetMap features)

Polygons and multipolygons: 640,000
Linestrings: 137,000

Karalis et al. *Extending the YAGO2 Knowledge Graph with Precise Geospatial Knowledge*. ISWC 2019.



YAGO2geo data sources

The YAGO2geo knowledge graph is constructed by enriching YAGO2 with data from the following sources:

- The [Greek Administrative Geography](#) (GAG) dataset
- [Administrative divisions data for the United Kingdom](#) obtained from Ordnance Survey and Ordnance Survey Northern Ireland
- [Administrative divisions data for Ireland](#) obtained from Ordnance Survey Ireland
- [Administrative divisions data for the USA](#) obtained from the United States Census Bureau
- [Administrative divisions data from the Global Administrative Areas dataset](#) (GADM)
- the following classes of [OSM features](#): natural, waterways, landuse and leisure, places

The Ontology of YAGO2geo

The ontology of YAGO2geo is defined by enriching the ontology of YAGO2 with:

- the ontologies of the **administrative geographies of Greece, UK, Ireland and USA**
- the ontology of the Database of Global Administrative Areas (GADM)
- an ontology for the part of OSM covered

The Knowledge Graph

The knowledge graph (instances) is constructed by **extending YAGO2** with new triples encoding **thematic and geospatial information** from the above data sources using their ontologies.

In addition, `owl: sameAs` triples are added for objects in two different data sources that refer to the same real world entity.

Example: the geoentity `hellenic_republic_390903` of YAGO2 is identical to the entity `GRC` of GADM since they both represent the country Greece. Therefore the triple

`hellenic_republic_390903 owl: sameAs GRC`
is added.

The Knowledge Graph

The **matching phase** for identifying identical entities consists of applying two filters:

- the label similarity filter (Jaro-Winkler similarity)
- the geometry distance filter (Euclidean distance in the WGS:84 coordinate system smaller than 0.2 degrees).

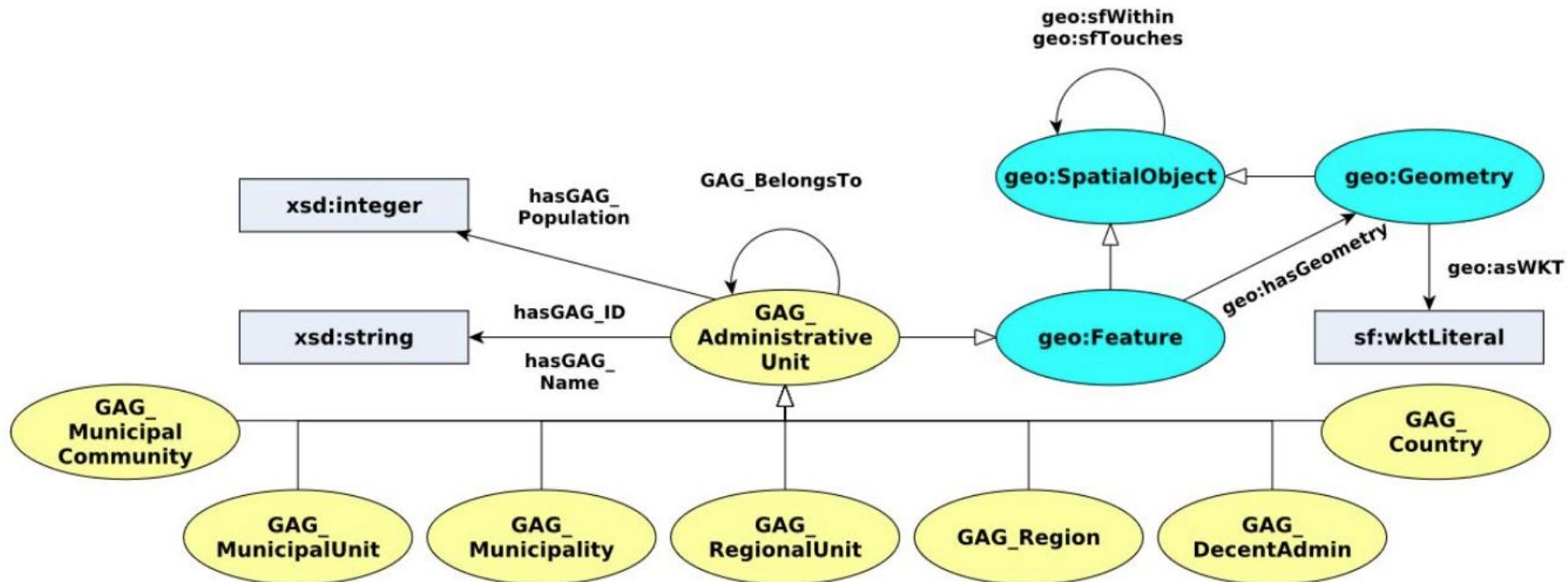
The methodology is based on the methodology that was used in YAGO2 when integrating information from GeoNames. A similar approach has been used in LinkedGeoData.

The Greek Administrative Geography (GAG)

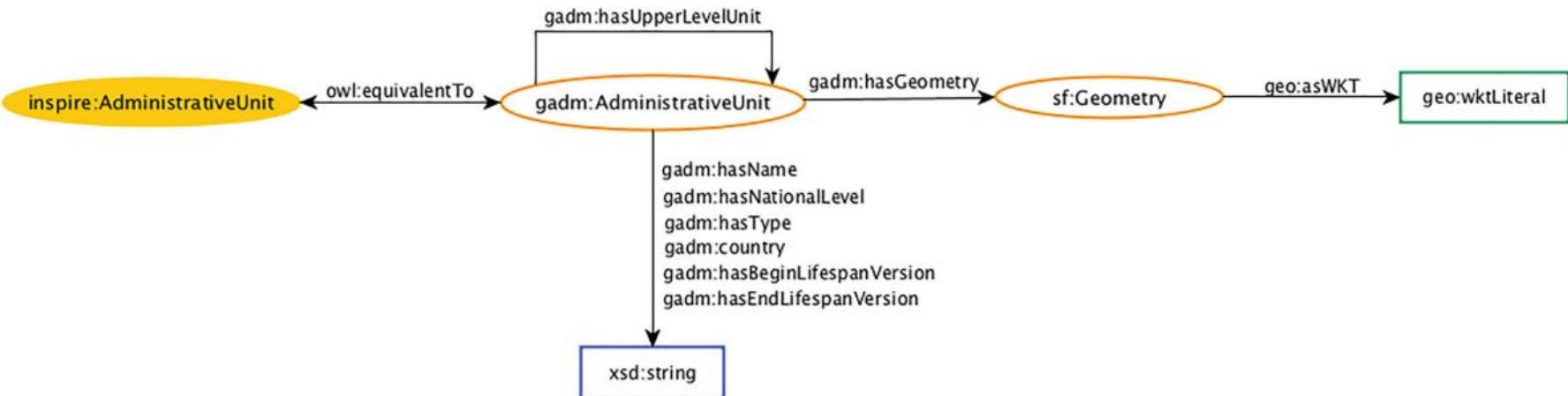


See
[https://en.wikipedia.org/wiki/
Kallikratis_Programme](https://en.wikipedia.org/wiki/Kallikratis_Programme)

The ontology of YAGO2: GAG



The ontology of YAGO2: GADM



An Example from YAGO2geo

```
gag:Olympia
  rdf:type gag:MunicipalCommunity;
  gag:hasGAG_Name "Ancient Olympia";
  gag:hasGAG_Population "184"^^xsd:int;
  geo:hasGeometry geo:OlympiaGeometry.
```

Ancient Olympia



An Example from YAGO2geo

```
geo:OlympiaGeometry
rdf:type geo:Geometry;
geo:asWKT "MULTIPOLYGON(((308511.906249999 4201042,308763.8125
4200714, 308840.09375 4200629,308939.3125 4200545,.....,
308390.000000001 4201276,308451.593749999 4201167,308467
4201125,308511.906249999
4201042));<http://www.opengis.net/def/crs/EPSG/0/2100>"^^sf:wktLiteral.
```

Ancient Olympia



YAGO4geo

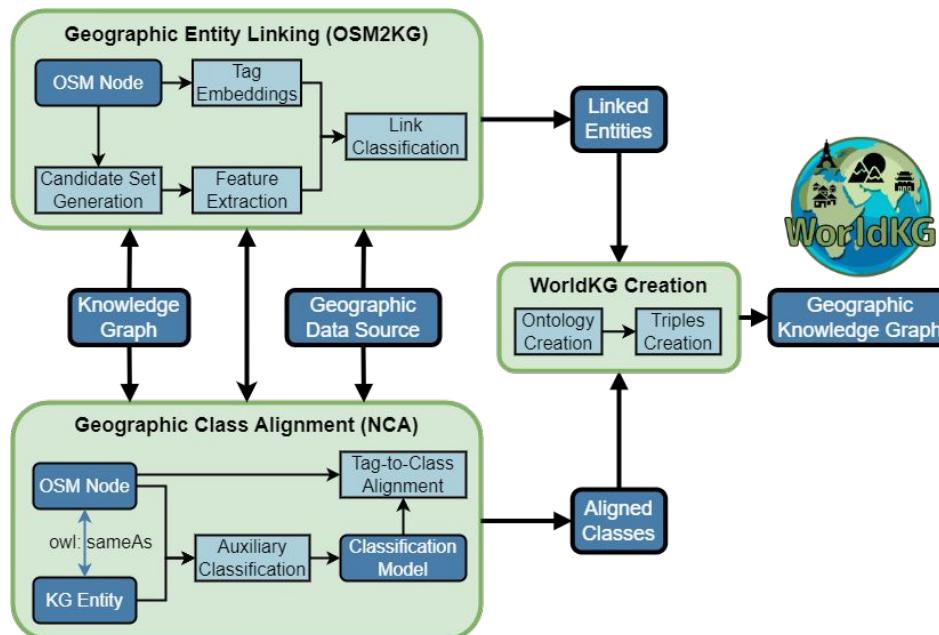
We have shown how to extend YAGO4 with rich geospatial information in the spirit of YAGO2geo.

The idea here was to use the schema.org facilities for representing geospatial information since YAGO4 heavily relies on schema.org.

However, the **limited geometric types of schema.org** (e.g., multipolygons are not supported) did not allow us to come up with an interesting geospatial knowledge graph.

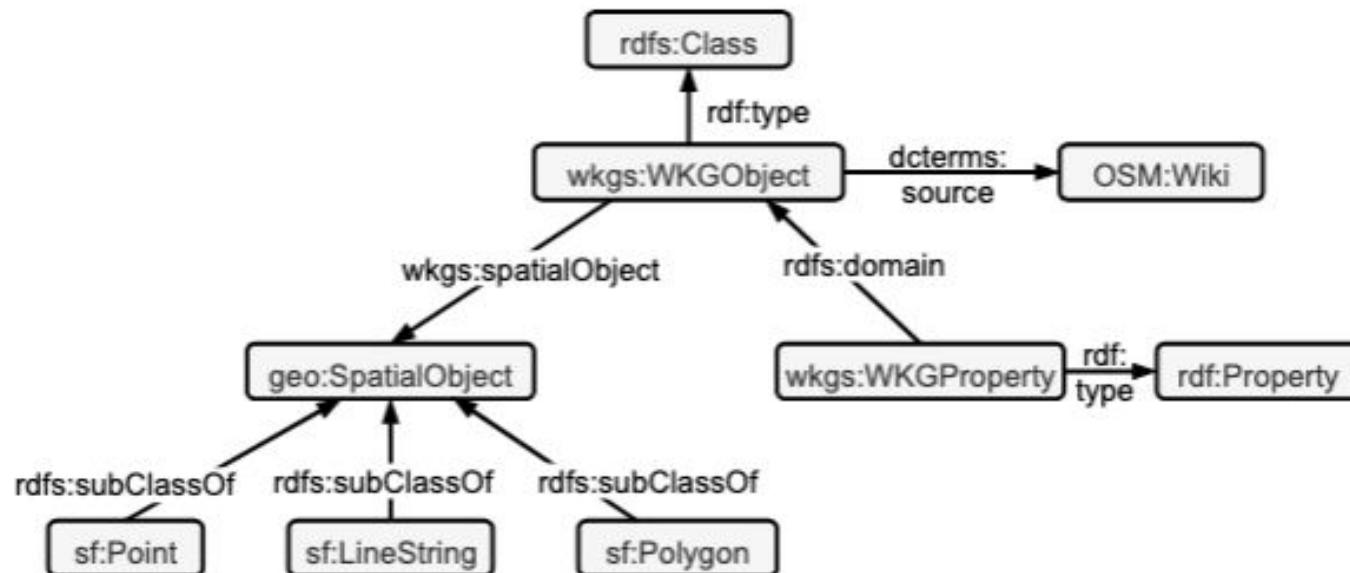
Geospatial Knowledge Graphs

- **WorldKG** (makes OpenStreetMap data available as a knowledge graph)



Dsouza, et al. *WorldKG: A World-Scale Geographic Knowledge Graph*. CIKM 2021.

The WorldKG ontology



Only OSM nodes i.e.,
only points

WorldKG classes

- WorldKG classes are constructed from **map features** of OSM. See https://wiki.openstreetmap.org/wiki/Map_features.
- The map feature list is used to construct a class hierarchy. In particular, the authors consider all keys in the feature map list as top-level classes (e.g., `natural`). Values assigned to the keys are represented as their subclasses.
- For example, from `natural=cave_entrance` becomes a subclass of `natural`.



WorldKG classes (cont'd)

- Only categorical values of keys are considered as subclasses in WorldKG.
- Other value types, e.g., Boolean or numerical values, are not considered as subclasses. Instead, the top-level class provided by the corresponding key is used.
- For example, an entity with a tag `building=yes` is typed as `wkgs:Building`.



WorldKG properties

- Properties and their values are created from OSM keys that have a valid English OSM Wiki page and are not mapped to own classes. For example, the value of property `wkgs:addrCountry` may be inferred from the key with Wiki page <https://wiki.openstreetmap.org/wiki/Germany> .
- Each class and property is linked to an OSM Wiki page via `dcterms:source`.

Schema Alignment with Existing KGs

- To link the WorldKG ontology to other existing ontologies, the authors determine equivalent OSM tags and classes from the Wikidata and DBpedia knowledge graphs.
- The **Neural Class Alignment** technique from the paper below is used.

WorldKG Statistics

Quantity	Count
Total triples	<u>828,550,751</u>
Total entities	<u>113,444,975</u>
Top-level classes	<u>33</u>
Sub-classes	<u>1,143</u>
Unique properties	<u>1,820</u>
Links to Wikidata classes	<u>40</u>
Links to DBpedia classes	<u>21</u>

Only points in the SPARQL endpoint currently.

13 million

1.53 million

In total, WorldKG covers 113,444,975 geographic entities, clearly more than Wikidata (8,621,058) and DBpedia (8,621,058).

Geospatial Knowledge Graphs

- **KnowWhereGraph** (integrates thematic and place-centric datasets into a geospatial knowledge graph).
- Pilot scenarios in disaster relief, agricultural land use and food-related supply chains.

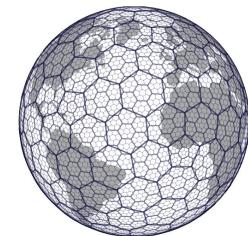
Janowicz et al. *Know, Know Where, Knowwheragraph: A Densely Connected, Cross-Domain Knowledge Graph and Geo-Enrichment Service Stack for Applications in Environmental Intelligence*. *AI Mag.* 43(1): 30-39 (2022)

Thematic Datasets					Place-Centric Datasets		
Dataset Name/Theme	Source Agency	Key Attributes	Spatial Coverage	Temporal Coverage	Place-Centric Dataset	Defining Authority	Spatial Coverage
Soil Properties	USDA	soil type, farmland class	Targeted regions in US	Current	S2 Cells	Google	Lvl 9 (Global), Lvl 13 (US),
Wildfires	USGS, USDA, USFS, NICF	wildfire type, burn severity, num. acres burned, contained date	US	1984-current	Global Administrative Regions	University of Berkeley, Museum of Vertebrate Zoology and the International Rice Research Institute	Global
Earthquakes	USGS	magnitude, length, width, geometry	Global (mag. over 4.5)	2011-01-01 to 2022-01-18			
Climate Hazards	NOAA	injuries, deaths, property damages	US	1950-2022	US Federal Judicial District	DoJ, ESRI	US
Expert - Covid-19 Mobility	Direct Relief	name, affiliation, expertise	Global	2021			
Expert - General	KWG, UC System, DR, Semantic Scholar	name, affiliation, expertise with spatiotemporal scopes	Global	unlimited	National Weather Zones	NOAA	US
Cropland Types	USDA	crop types (raster data)	US	2008-2021	FIPS Codes	NRCS	US
Air Qual. Obs.	U.S. EPA	AQI value, CO concentration	US	1980-2022	Designated Market Area	Nielen	US
Smoke Plumes	NOAA	daily smoke plumes extent	US	2010-2022	ZIP	ZCTA	US
Climate Observations	NOAA	temperature, precipitation, PDSI, PHSI	US	1950 - 2022	Climate Division	NOAA	US
Disaster Declaration	FEMA	designated area, program, amount approved, program designated date	US	1953 - 2022	Census Metropolitan Area	US Census	US
Smoke Plume Extents	NOAA	Smoke extent	US	2017 - 2022	Drought Zone	NDMC, USDA, NOAA	US
BlueSky Forecasts	Bluesky	PM10, PM5	US	2022-03-07	Geographic Name Information System	USGS	US
Transportation (highway network)	DOT	road type, road length, road sign	US	2014			
Public Health Observations	CDC, US Census, University of Wisconsin Population Health Institute	below poverty level, diabetes, obesity, mental health provider rate, annual mammogram, vaccinated, injury death	US	2017, 2021			
Public Health Infrastructure	HIFLD	pharmacies, hospitals, dialysis centers, public health departments	US	2017 - 2022			
Social Vulnerability	CDC/ATSDR	social vulnerability index	US	2018			
Hurricane Tracks	NOAA	max wind speed, min pressure	US	1851-2020			

Geospatial knowledge graphs



- **H3-GeoKG** is geospatial knowledge graph build from OSM data (nodes, ways and relations).
- The developers of H3-GeoKG use the **H3 discrete global grid** to harmonize the geometries that are extracted from OSM similar to KnowWhereGraph.
- The most important difference with KnowWhereGraph is that the discrete global grid uses a square-based grid cell geometry, whereas H3 uses a hexagonal-based grid cell geometry.
- The benefit is that in a hexagonal grid **the distance to all neighboring cells is uniform**, which is not the case for square- or triangular-based grids.



Other geospatial knowledge graphs

- CrowdGeoKG (Chen et al., 2017)
- HGeoKG (Li et al., 2025)

J. Chen et al. *CrowdGeoKG: Crowdsourced Geo-Knowledge Graph*. CCKS 2017.

Tailong Li et al. *HGeoKG: A Hierarchical Geographic Knowledge Graph for Geographic Knowledge Reasoning*. ISPRS Int. J. Geo-Inf. 2025.

Thank you!

