

# Exploring Visualization of Geospatial Ontologies Using Cesium

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**Abstract.** In recent years, there has been a substantial increase in the usage of geospatial data, not only by the scientific community but also by the general public. Considering the diverse and heterogeneous nature of geospatial applications around the world and their inter-dependence, there is an impending need for enabling sharing of semantics of such content-rich geospatial information. Geospatial ontologies form the building blocks for sharing of semantics of this information, thus ensuring interoperability. Visualization of geospatial ontologies from a spatio-temporal perspective can greatly benefit the process of knowledge engineering in the geospatial domain. This paper proposes to visually explore and reason over the instances of a geospatial ontology – the geopolitical ontology developed by the Food and Agriculture Organization of the United Nations using Cesium – a WebGL based virtual globe. It advocates the usage of Cesium for visualization of geospatial ontologies in general by demonstrating visualizations of geospatial data and their relationships.

**Keywords:** geospatial, ontology, visualization, cesiumjs, jowl, spatio-temporal, reasoning

## 1 Introduction

In recent years, the consumption of geospatial data has increased tremendously[1]. Location based services form a major consumer of the geospatial data consumption demographic. Effective visualization of geospatial ontologies can aid in exploration and understanding of the domain knowledge represented by the ontology and helps reduce information overload on the user. This paper proposes to exploit the 3-dimensional visualization capabilities of Cesium – a WebGL based virtual globe to effectively represent the instances of a geospatial ontology and reason over them using SPARQL queries and render the results on the globe.

### **1.1 Geospatial Ontologies and Linked Data**

Geospatial Ontologies cater to modeling, analyzing and visualizing multi-modal heterogeneous information in the geospatial domain[2]. They help establish the semantics of this geospatial information promoting information exchange and interoperability. The geographical data typically involves latitude, longitude and the altitude, supplemented by the temporal information and the feature of interest. Geospatial concepts and relationships are different from those of the non-geospatial data due to their spatio-temporal nature. This calls for a need to focus on effective visualization, analysis and exchange of geospatial data.

Linked Data forms an integral part of the Semantic Web ecosystem. Linked Data can be referred to as the collection of inter-related data-sets on Web[3]. It provides access not only to the data itself, but also to the relationships among the data. It facilitates interoperability of large scale data. It also enables querying and reasoning to be performed on this data, thus attempting to fulfill the Semantic Web vision[4]. It helps increase the value of the data itself, by making it more accessible, shareable and understandable. Geospatial Linked Data refers to the Linked Data enriched with a geospatial dimension - spatial and temporal attributes. Advances in the field of Geospatial Linked Data effectively contribute to the vision of the Geospatial Semantic Web first proposed by Max Egenhofer[5].

### **1.2 Cesium – A WebGL based Virtual Globe**

Cesium<sup>1</sup> is a free and open source WebGL based JavaScript library that visualizes the earth as a globe in 3 dimensions on the web browser. It was developed by Analytical Graphics, Inc (AGI) in 2011 for dynamic data visualization in space. Over the years it has evolved to help visualize and serve industries from geospatial and oil and gas to agriculture, real estate, entertainment, and sports.

Cesium allows users to pan and zoom around the globe in 3D. It has a timeline feature that can be exploited to visualize multi-temporal data. Cesium allows rendering of ‘entities’[6] on its globe to visualize objects in 3D on the earth surface. It allows ‘entities’ to be interactive, so one can click an entity of interest and be presented with its meta-data. The entities can be placed honoring the geographical coordinates (latitude, longitude and altitude) on the globe.

### **1.3 jOWL**

jOWL<sup>2</sup>[7] is a semantic JavaScript library for navigating and visualizing OWL-RDFS documents. It extends the jQuery library with its ability to parse and visualize semantic web documents. It also supports use of abstract SPARQL-DL for querying

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<sup>1</sup> <https://cesiumjs.org/>

<sup>2</sup> <http://jowl.ontologyonline.org/>

and reasoning over ontologies. This paper proposes to use jOWL over Cesium for parsing and reasoning over the Geopolitical Ontology.

## **2 Visualization of Geospatial Ontologies using Cesium**

Cesium can be used to visualize information extracted and parsed from ontologies as ‘entities’ and render it in 3-D on the virtual globe, thus providing the user an immersive and a riveting experience. The spatial aspect of data can easily be modeled on Cesium, since it supports the cartographic coordinate system. The third dimension in Cesium could be used to visualize a feature of interest such as the temperature, air pressure or wind speed for better user interaction and understanding. For data, that is dependent on the altitude such as the air pressure or the wind speed, using the third dimension could prove to be effective in visualizing the change in this data. The temporal features of data too can be visualized using the Time-line[8] widget of Cesium. Color is another aspect of Cesium that can be exploited to visualize a parameter in Cesium. Cesium entities can be colored depending on the intensity of a predefined parameter from the geospatial ontology. For instance, in case of a Semantic Sensor Network based Ontology<sup>3</sup> of a Weather Station, we could use the temperature data to be visualized using colors on the regions. So a region with greater temperature value can be shown on the higher side of the color spectrum accompanied by the appropriate color legend. The meta-data or other additional information about an ‘entity’ can be rendered using the ‘Info-Box’ widget in Cesium.

Along with the visualization benefits that Cesium brings along, the fact that it runs inside a web browser is also a big plus today, where all applications are expected to be ubiquitous. Thus Cesium proves to be an effective tool in visualization of geospatial data-sets.

### **2.1 Dataset**

For this paper, the Geopolitical Ontology[9] developed by the Food and Agriculture Organization of the United Nations has been visualized and reasoned upon. The ontology comprehensively lists all countries of the world with their geographic extent, geographic and socio-economic information and categories and groups they belong to. Geospatial concepts such as the geographic extent and relationships such as “hasBorderWith” have been focused on in the demo implementation of this paper. The instances of “hasStatistics” predicate depicting population and Gross Domestic Product of countries have been visualized over the Cesium globe. The dataset has also been reasoned upon using SPARQL-DL for obtaining the class a country belongs to, the countries that share its border and the groups it is aligned with.

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<sup>3</sup> <https://www.w3.org/2005/Incubator/ssn/ssnx/ssn>

To explore visualization of fine grained data such as population over Cesium, the sample dataset of ORNL's LandScan<sup>4</sup> has been used. The LandScan dataset is available in the .lyr format and cannot be directly consumed by Cesium. It required conversion from the raster to a vector format and was later exported into GeoJSON. The GeoJSON was then parsed and transformed into a simple ontology with the class "Cell" having the following data properties - "latitude", "longitude" and "value". The cell represents a 1km spatial resolution pixel on the earth surface and the value represents the number of people in the cell. The LandScan data consisting of instances from the Sample LandScan Dataset of Cyprus has been published<sup>5</sup> as linked data as a part of this research study.

## 2.2 Visualization of the Geopolitical Ontology

The implementation demo that supports this paper uses Cesium and jOWL javascript libraries for visualization and reasoning. The geographic extent for each of the countries has been extracted and parsed from the geopolitical ontology to render it on the globe. The bounding boxes of each of the countries from the ontology, visualized on the globe are shown in Fig. 1. The bounding boxes are rectangle geometric entities in Cesium. For this proof of concept implementation, the colors are assigned randomly, with an alpha value of 0.5, thus ensuring transparency for the visibility of underlying Bing Maps imagery. Triples with <hasStatistics> predicate and Population and Gross Domestic Product objects can be selected and visualized on the globe.

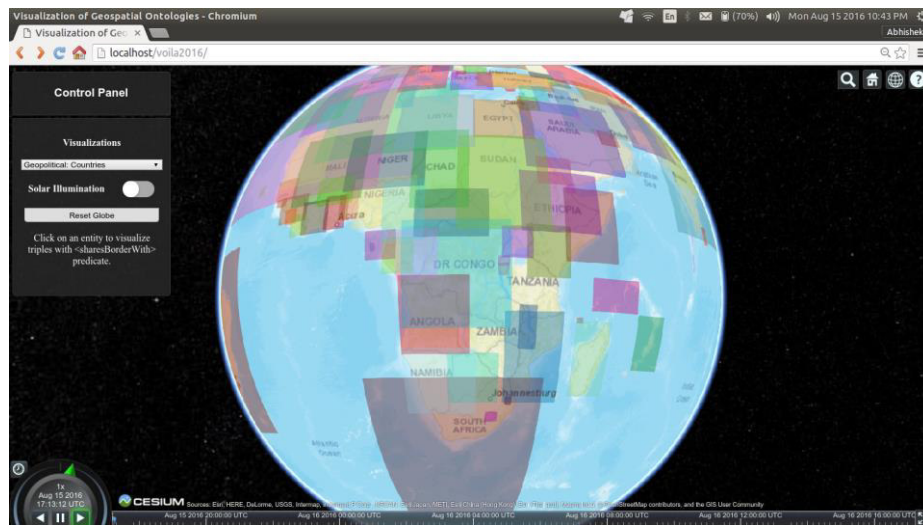


Fig. 1. Visualization of the Geopolitical Ontology using Cesium

<sup>4</sup> [http://web.ornl.gov/sci/landscan/landscan2011\\_sample.shtml](http://web.ornl.gov/sci/landscan/landscan2011_sample.shtml)

<sup>5</sup> [http://home.iitb.ac.in/~abhishekvpotnis/voila2016/population\\_cyprus.owl](http://home.iitb.ac.in/~abhishekvpotnis/voila2016/population_cyprus.owl)

The user can pan and zoom around globe with the countries being identified by their bounding boxes. The bounding boxes are clickable entities. Clicking on a bounding box fires up three SPARQL-DL queries over the geopolitical ontology as a proof of concept demonstration.

SPARQL-DL Query 1: *Type(COUNTRY\_NAME +",?class)*

It returns the class that the country or region belongs to that the user clicked. The ontology identifies the following classes for a country or region : self governing, non-self governing, disputed and other.

SPARQL-DL Query 2: *PropertyValue(COUNTRY\_NAME,hasBorderWith,?country)*

It returns the countries that the country of interest shares its border with. 'hasBorderWith' is a spatial relationship in the geopolitical ontology. This spatial relationship has been effectively visualized in the demo that supports this paper.

SPARQL-DL Query 3: *PropertyValue("COUNTRY\_NAME,isInGroup,?group)*

It returns the groups that the country of interest belongs to. The ontology has identified the multiple groups and sub-groups that a country or a region may belong to.

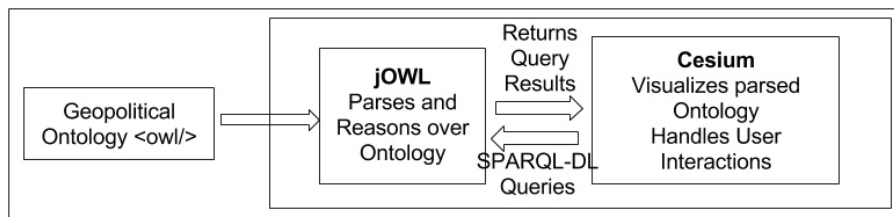


Fig. 2. Architectural Overview of the Proof Of Concept Implementation

The queries are run in real-time on the client-side over the Geopolitical ontology. The results are parsed and rendered in the info-box widget of Cesium. The results of the second query which exploits the 'hasBorderWith' spatial relationship are sent over to Cesium, where the list of countries are mapped to their bounding boxes. The bounding boxes of the neighboring countries and the country of interest are retained on the globe, while other bounding boxes are erased. The info-box at the right, displays the queries along with their results. The queries written in SPARQL-DL are executed over the geopolitical ontology using the jOWL library. Fig 2. shows the architectural overview of the proof of concept demonstration. The Geopolitical Ontology is parsed using jOWL and is rendered on the globe using Cesium. The geographic extent in the form maximum and minimum latitudes and longitudes are extracted from the parsed ontology and relayed to Cesium for rendering the bounding boxes. Cesium handles user interactions and relays them to jOWL for SPARQL-DL query evaluation. The query results are later returned to Cesium for rendering.

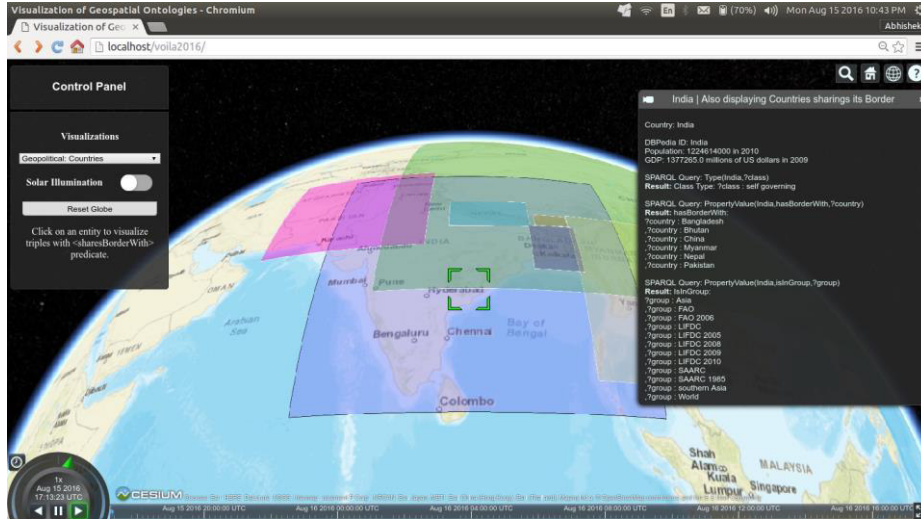


Fig. 3. Visualization of Spatial Relationship 'hasBorderWith' from the Geopolitical Ontology

Fig. 3 shows the country of interest being India. The countries that share their borders with India are shown along with India, while others are erased. The info-box to the right lists the SPARQL-DL queries along with their results. The info-box also lists the Name of the Country, its Population, its GDP and its DBPedia ID, all extracted from the Geopolitical Ontology. The DBPedia ID could later be used to access additional

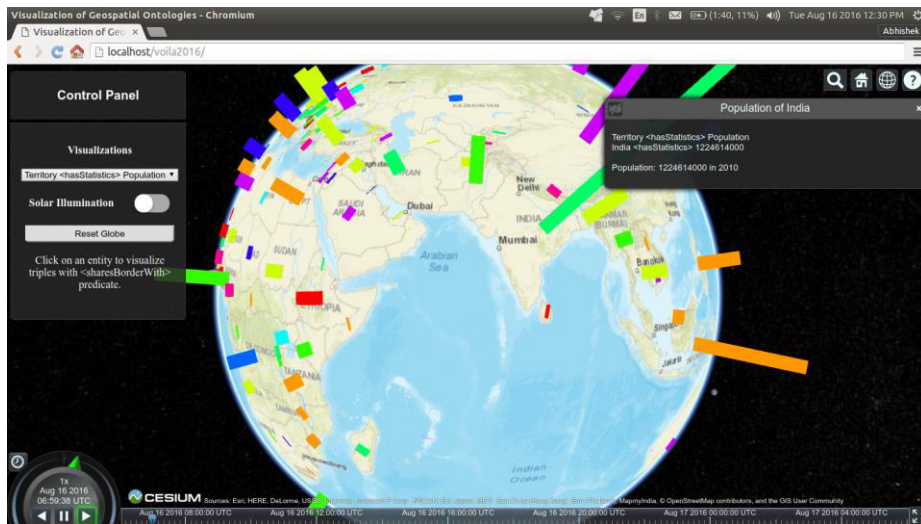


Fig. 4. Visualization of triples with 'hasStatistics' predicate depicting Countries' Population

information from DBPedia which is not otherwise available in the Geopolitical Ontology. The population of countries has been visualized in Fig. 4. Hovering over a

bar will bring up the population value that the bar represents. From the visualization, it is evident that India and China are the most populous countries.

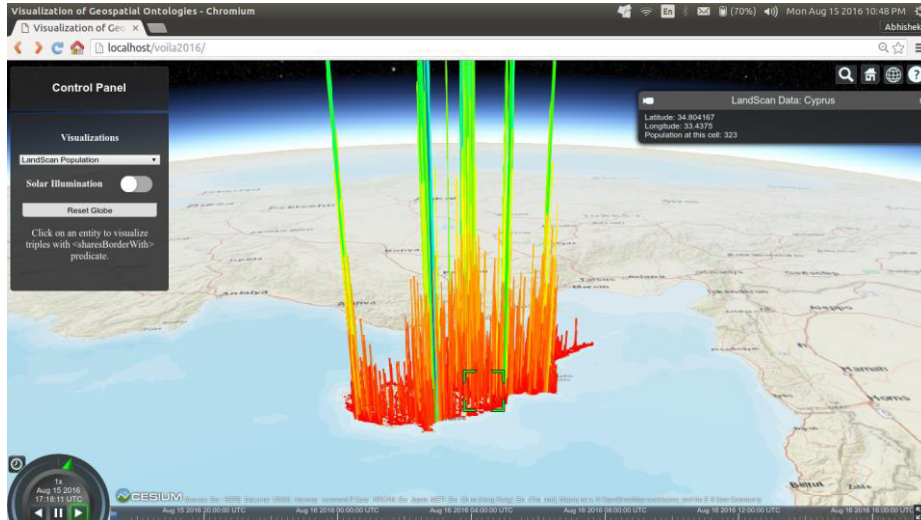


Fig. 5. Visualization of Cyprus LandScan Sample Linked Data

Fine-grained data such as the LandScan Sample Dataset of Cyprus has been visualized in Fig. 5. A simple ontology containing the class ‘cell’ having data properties – latitude, longitude and value along with instances acts as the input for this visualization. The jOWL library has been used to parse the ontology and its instances. Cesium thus effectively visualizes the population per cell in 3D. Hovering over the data brings up the latitude, longitude and the population at that cell. This allows user to visually explore the LandScan data. From the visualization, one can infer that the coastal region of Cyprus has lesser population as compared to the interiors. One can even point out the population hotspots from such visualizations.

The user can return to the initial state of full coverage of the geopolitical ontology by simply clicking outside a bounding box or by using the ‘Reset Globe’ button on the Globe Control Panel. There is also a feature to toggle the Solar Illumination on the globe in the Globe Control Panel on the left. The proof of concept implementation can be demoed at <http://home.iitb.ac.in/~abhishekvpotnis/voila2016/>.

### 3 Conclusion

This paper demonstrates the visualization capabilities of Cesium virtual globe for geospatial ontologies along with reasoning using the jOWL semantic library. The proof of concept demonstration reasons and visualizes the results of the spatial relationship of the neighboring countries with the country of interest. It does not account for visualization of temporal attributes due to lack of temporal data in the

geopolitical ontology, however they can be visualized effectively using Cesium's Timeline widget. This paper focuses on the visualization of data properties of individual classes. Future work would involve focusing on the object properties to visualize relations between individual classes. This study, in the future, also aims to explore visualization of relationships between population, agricultural production, GDP and HDI using AGROVAC LOD[10] and other sources of linked data using Cesium. Another direction that this research could explore is support for federated SPARQL queries over multiple ontologies to visualize multi-source data instances simultaneously.

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