Exploring the Web of Spatial Data with Facete

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ABSTRACT
The majority of data (including data published on the Web
as Linked Open Data) has a spatial dimension. However,
the efficient, user-friendly exploration of spatial data re-
mains a major challenge. We present Facete, a web-based ex-
ploration and visualization application enabling the spatial-
faceted browsing of data with a spatial dimension. Facete
implements a novel spatial data exploration paradigm based
on the following three key components: First, a domain inde-
pendent faceted filtering module, which operates directly on
SPARQL and supports nested facets. Second, an algorithm
that efficiently detects spatial information related to those
resources that satisfy the facet selection. The detected rela-
tions are used for automatically presenting data on a map.
And third, a workflow for making the map display interact
with data sources that contain large amounts of geometric
information. We demonstrate Facete in large-scale, real
world application scenarios.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User
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Selection process

Keywords
SPARQL; RDF; faceted search; geospatial data; property
path retrieval; map visualization

1. INTRODUCTION
The growth of the Linked Open Data (LOD) cloud\(^1\) goes
hand in hand with an increasing amount of geospatial infor-
mation being made available for online querying via SPARQL.

\(^{1}\)http://lod-cloud.net/

For instance, the community projects DBpedia and Linked-
GeoData provide access to more than 1.3 million and 2 bil-
lion point geometries based on Wikipedia and OpenStreet-
Map data, respectively. Government agencies have started
maintaining public SPARQL endpoints, such as Ordinance
Survey\(^2\) and the European Environment Agency\(^3\). The lat-
ter, for instance, hosts 123 RDF graphs that contain a siz-
able number of resources described using the WGS84 vocab-
ulary.

Yet, the user-friendly exploration of spatial data access-
ible via public SPARQL remains a major challenge, especially
due to performance, volume, scalability and UI complexity
issues. In this demo, we present the spatial data explo-
ration and visualization application Facete, depicted in Fig-
ure\(^4\). Facete is a client-side JavaScript application, which
interacts with a server-side SPARQL endpoint. The ma-
jor problem when exploring spatial data is that the spatial
dimension is in most cases not directly attached to all the
data items. For example, a dataset about multi-partner re-
search projects would contain entities for the projects itself,
the project partners, their legal entities, the branch offices
developers may reuse and customize as needed.

\(^{2}\)http://data.ordnancesurvey.co.uk
\(^{3}\)http://semantic.eea.europa.eu/sparql
\(^{4}\)http://www.v3.org/2003/01/geo/vgs84_pos
\(^{5}\)https://github.com/GeoKnow/Jassa

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2. THE FACETE SPARQL EXPLORER

Facete is a Single Page Application (SPA) whose user interface comprises several UI components, which are depicted in Figure 1 and explained in the following. In the top area, there are elements that enable the user to select a SPARQL endpoint and choose from one or more of its contained named graphs. The main panel is divided into three columns containing a set of widgets with the following functionality: 1. Selection. The first widget, labeled Facet, shows a facet tree that corresponds to the properties of all resources that match the set constraint. If there are no constraints, all resources that appear as a subject in the selected graphs are matched. Three actions can be performed for node in the facet tree: A click on the facet’s name lists the facet’s values in the Facet Value widget, where these values can be used for defining constraints. Clicking the caret symbol toggles the display of corresponding child facets. These are the properties of the the selected facet’s values. Lastly, a facet can be pinned as a column to the Table View. Note, that the root of the facet tree is formed by a facet labelled Item. This facet’s values correspond to the set of resources in subject positions of the selected RDF graphs. The Facet Values widget enables a user to paginate through a selected facet’s values and optionally filter these values by a search term. Furthermore, clicking the checkbox next to a value creates a constraint. The Filters widget lists all active constraints. Individual constraints can be removed by clicking their entry, whereas the Clear Filters button purges them all.

2. Data. The middle area contains the Table View, which lists a table whose content is based on resources that match the active constraints and the facets that were pinned as columns. Columns can be sorted by clicking the caret icons. Multiple orders are supported by holding the shift key down while clicking.

3. Geographical. The Geo-Link drop down menu enables the user to choose from property paths connecting the resources that match the constraints with those that can be shown on the map. By default, the option automatic is enabled, which always picks the shortest path among the found ones. The Map widget displays markers corresponding to the selected resources and the geo-link. Blue boxes indicate areas that contain too many markers to be shown at once. These boxes disappear when sufficiently zoomed in. Clicking a marker shows its details in the Detail View. The Detail View shows the excerpt of the Table View that corresponds to the selected marker(s).

3. A SOPHISTICATED USE CASE

We demonstrate Facete in a use case scenario, which to the best of our knowledge, none of the existing SPARQL browsers can serve easily.

The dataset about ICT research projects under EU-FP7[^ICT] for which an RDF version exists[^RDF] contains comprehensive information about funded projects, partner organizations and particularly also how much money was granted to partners in FP7-ICT projects. The most important classes and their relations are as follows: Every Project is related to a set of Fundings (grants), whereas each instance represents the amount of money granted to a single project partner (beneficiary). Partners carry address information, which includes resources for the country and city. The cities’ geo-coordinates were obtained based on interlinking them with places in LinkedGeoData[^LGDO][^LGDO] (LGD). This model is depicted in Figure 2.

There are several questions one may ask, such as: What are the projects related to a certain country? Where are the partners of a particular project located? How much money was granted to partners in a specific project?

With Facete, the following procedure can be performed to answer these questions:

- First, select the type facet, and constrain it to the value Project. The main table will now only list project names, and the map component will automatically determine connections that link projects to coordinates.
- A project is related to a country if there is at least one project partner located in that country. Expanding the funding facet will list several nested facets, including partner and amount. We can then dive deeper into the facet tree by expanding first partner and then address. This reveals a country facet. Clicking it’s label lists its corresponding facet values, which can then be constrained to a country of interest, such as “Germany”. The main table, as well as the map, will update to only show projects related to this country.
- A project can then be singled out by clicking the label of the Item facet and constraining it to the resource of a specific project, such as LOD2. The map view now only shows those partners that are located in the previously selected country.
- So far, the main table only listed named projects. Pinning the partner and amount facets to the main table shows this project’s related information. Drop the constraint on countries for the map to show partners world wide.

Note, that this use case stands exemplary for a large number of similar use cases involving spatial data.

4. CONCEPTS

In this section we briefly outline the key concepts used in Facete, which are related to faceted search, detection of property paths that connect concepts and dealing with large amounts of spatial data.

[^RDF]: [http://fp7-pp.publicdata.eu](http://fp7-pp.publicdata.eu)
[^LGDO]: [http://linkedgeo.data.org](http://linkedgeo.data.org)

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![Figure 2: Excerpt of the CORDIS dataset model showing the path how projects are related to geo-coordinates.](image-url)
4.1 Facted Search

There are several systems that support faceted filtering of a set of RDF resources by immediate (possibly predefined) properties. However, faceted search over indirectly related properties is much more challenging. Facete’s approach is based on the following key concepts:

- A **SPARQL concept** is a pair comprising a SPARQL graph pattern and a variable thereof. As such, it intentionally describes a set of resources. For instance, the pair \( \{ \{ ?s a Project \} \), ?s \} \) describes the set of project resources. SPARQL concepts are the key enabler for indirect faceted search. Internally, Facete uses them to represent any set of resources, i.e. the set of facets, the set of child facets, the set of facet values and the set of resources with geometric information.

- **Property Steps** are used to navigate from a set of resources to a related set of resources by following a specific property. A direction attribute determines whether to follow that property in forward or inverse direction. Hence, a destination SPARQL concept can be obtained from a given origin SPARQL concept and a property step.

- A **Property Path** is a sequence of property steps.

- **Constraint Specifications** express constraints via references to property paths. Constraint specifications are internally translated to corresponding SPARQL graph patterns.

4.2 Finding Connections between Concepts

Due to data modeling, the spatial dimension is in most cases not directly attached to instances of a certain type. In order to visualize the spatial dimension of such objects efficiently and intuitively we need an approach to find connecting property paths between two arbitrary SPARQL concepts. As our use case demonstrates, these paths can become relatively long, and naive path discovery approaches are not feasible. Our approach is outlined as follows: Because we are only interested in the detection of property paths, we pre-compute a property join summary. The basic SPARQL query for this purpose is:

```sparql
CONSTRUCT { ?p1 :joinsWith ?p2 } {
    SELECT DISTINCT ?p1 ?p2 {
    }
}
```

Conceptually, we could search for arbitrary complex paths, such as ones that include cyclic (same property followed multiple times in the same direction) and zig-zag (forward and backward on the same property traversals. However, for our use cases the restriction to directed acyclic paths leading from a source concept to a target concept was sufficient: We query the source concept for all of its properties ?p, and conceptually add triples (:source :joinsWith ?p) to the join summary. Thereby :source is a distinguished resource representing the source concept. From a target concept’s graph pattern, such as \( \{ ?s \text{geo:long} ?x \text{geo:lat} ?y, ?s \} \), we can infer that we need to search for properties that according to the join summary are connected to both geo:long and geo:lat. As a consequence, we can query the join summary for a set of candidate target properties using:

```sparql
SELECT DISTINCT ?p {
    ?p :joinsWith geo:long, geo:lat
}
```

If the extensions of the source and target concepts have resources in common, this query’s result set includes :source as a candidate.
We can now search for candidate paths on the join summary that connect :source with each of the candidate properties. For each candidate path we then fire an ASK query to check whether the given dataset contains an instance of it. Those paths that actually exist, are then listed in Facete’s Geo-Link drop down box.

Note, that this approach is independent of any concrete vocabulary.

4.3 Display of large Amounts of Geometries

Some spatial RDF datasets, such as DBpedia or Freebase, contain significantly more spatial information than what can performance and bandwidth wise be reasonably retrieved and displayed on a map in a web application. Facete handles such cases using a quad tree data structure:

- Based on the users constraints on the facets and the geo-link, a corresponding SPARQL concept, named geo-concept, is created. The geo-concept specifies the set of resources to be shown on the map.
- A count of the number of instances matching the geo-concept is requested. If the count is below a configured threshold, all instances are retrieved at once and placed into the root node of the quad tree.
- If this count exceeds the threshold, the extent of the whole map is split recursively into four tiles of equal size. The recursion stops if either a maximum depth is reached, or if the tiles have reached a certain relative size when compared to the map viewport (e.g. when about 4x4 tiles are visible). For each tile, the geo-concept is then modified to only refer to resources within that tiles’ bounding box. A tile’s resources are only retrieved, if the new count is again below a configured threshold.
- Tiles that still contain too many geometries are rendered as boxes on the map.

An example of such display is shown in Figure 3 which shows a subset of the approx. 20,000 resources with geo-positions in Germany. For each set of constraints, Facete creates a new quad tree that acts as a cache for the user’s current configuration.

5. RELATED WORK

The RelFinder system [2] is capable of finding property paths connecting a pair of resources, whereas Facete searches for paths between SPARQL concepts. Over the past decade, faceted search has become omnipresent, such as in web shop and content management systems. Apache Solr[9] is a popular system that offers extensive faceted search features, however, it does not offer native SPARQL support and thus requires pre-processing of RDF data. Virtuoso[10] and the Virtuoso faceted browser[11] support changing the focus from one set of resources to a related one (known as pivoting). However, with these systems, the user actually navigates between related list views of resources, whereas in Facete the user pins facets as new columns to the table view.

6. CONCLUSIONS AND OUTLOOK

In this demo we present Facete, an advanced faceted browser for SPARQL accessible data with geo-spatial capabilities. We demonstrate Facete’s potential based on a sophisticated use case which requires retrieval of information from a set of indirectly related resources. Users are empowered to create customized tabular data views showing attributes they are interested in. Based on related geometric information, these data are also shown on a map. Facete’s three key concepts are: (1) The generic faceted filtering engine, that supports showing and filtering by nested facets, (2) the property path detection, which efficiently detects how resources can be shown on the map based on indirectly related spatial information, and (3) how the system offers an interactive map display even for large amounts of geometric information.

There are a number of directions for future work: One is adding support for aggregation functions. Another logical step is to define more advanced views than the current table and map. Users should then be empowered to connect such views to their created data table. For instance, once a user has defined a table which lists for each city or country the total amount of money given to partners located in it, then based on this information a heat map view could be rendered. Our vision is, for the creation of visualizations from Linked Data to become as simple as in spreadsheet applications, where advanced chart and map visualizations can be created with a few clicks.

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