

# Finding and explaining relations in a biographical knowledge graph based on life events: Case BiographySampo

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## Abstract

This paper presents a knowledge-based approach for finding and explaining “interesting” semantic relations between persons and places in a knowledge graph. As a case study we use the BiographySampo knowledge graph which includes life events extracted from the short biographies of 13 100 prominent historical persons in Finland. We use SPARQL CONSTRUCT queries to extract connections and create human readable explanations based on the events in the knowledge graph, and then offer faceted search tools to search and filter the connections. The results can then be visualized using various charts and maps.

## Keywords

knowledge discovery, linked data, event-based model

## 1. Knowledge Discovery as Relational Search

**Research Problems** This paper addresses the following problem of knowledge discovery [1] in Cultural Heritage (CH) [2] knowledge graphs (KG) [3]: *How are two concepts related to each other?* Semantic connections in a KG can be found between individual entities (e.g., how is Vincent van Gogh related to the village of Auvers-sur-Oise or to Paul Gaguin?) but also between more general concepts (e.g., how are Dutch impressionists related to France?). Such semantic connections can be based on various criteria for the underlying connecting paths. The problem of finding semantic connections has been called as association finding [4] or as relational search (RS) [5, 6, 7, 8]. We address the following challenges of solving RS problems:

1. *How to disambiguate “interesting” [9] or even “serendipitous” [10] semantic connections from non-interesting ones.* Concepts in a KG are related to each other in many ways, but only few of them are of interest to the user. For example, that van Gogh and Gaguin are instances of the class `owl:Class` is not interesting.

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<sup>1</sup>Serendipity means ‘happy accident’, ‘pleasant surprise’, or ‘fortunate mistake’. According to the Merriam-Webster dictionary, serendipity is “the faculty or phenomenon of finding valuable or agreeable things not sought for”.

2. *How to explain a semantic connection to the end user?* Finding out an interesting connection is not enough if the system cannot explain to the end user why the connection could be interesting. This problem is related to the field of explainable AI [11, 12].

In our approach, we precalculate connections between two entities, in our case people and places, based on predefined forms that represent connection types that are deemed interesting using SPARQL CONSTRUCT queries. These predefined connections and their explanations can then be explored using faceted search [13], based on hierarchical ontologies that represent the properties of the entities. This allows for finding serendipitous connections between single entities through an exploratory process, but also importantly finding connections between larger groups of entities.

3. *How to formulate the query and query results when searching for connections.*

**Related Work** In relational search the *query* consists of two or more resources, and the task is to find interesting semantic relations between them. The approaches [14] differ in terms of the query formulation, underlying KG, methods for finding connections, and representation of the results. In [4] the idea of searching relations is applied for association finding in national security domain. CultureSampo<sup>2</sup> [15, 16] contains an application where connections between two persons were searched using a breadth-first algorithm. In RelFinder<sup>3</sup> [17, 5, 6, 7] the user selects two or more resources, and the result is a visualized graph showing how the query resources are related with each other. WiSP [8] finds several paths with a relevance measure between two resources in the WikiData<sup>4</sup> KG, using ranking algorithms. The query results are graph paths that can be ranked based on how familiar the elements related to the information are to the user [18]. Some applications, e.g., RelFinder and Exclass [19], allow filtering relations between two entities with facets, but the user typically has to preselect the entities before faceted search can be used. A main challenge in these systems is how to select and rank the interesting paths. Ranking relations is discussed, e.g., in [14, 20].

In [21] two algorithms and a tool RECAP are presented for explaining connections: E4D based on explaining individual paths between given resources in a knowledge graph, and E4S where additional schema information and a target predicate are used for focusing on more interesting explanations. In contrast to these, our method is not based on the schema but on additional domain knowledge patterns of interestingness, that are used both for finding the connecting paths in the first place, and for explaining them. Explanations have been studied also in the context of recommender systems [22].

This paper presents and applies a knowledge-based approach to the research problems above and discusses experiences in applying the approach in the in-use semantic portal BiographySampo [23, 24] “BiographySampo – Finnish Biographies on the Semantic Web”<sup>5</sup>. BiographySampo publishes biographical data included in the National Biography of the Finnish Literature Society<sup>6</sup> about historical Finnish persons, and is part of the Sampo series of LOD services<sup>7</sup> and portals [25]. The contents are expressed as Linked Open Data (LOD) using the

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<sup>2</sup><http://www.kulttuurisampo.fi>

<sup>3</sup><http://www.visualdataweb.org/refinder.php>

<sup>4</sup><http://wikidata.org>

<sup>5</sup>Project: <https://seco.cs.aalto.fi/projects/biografiasampo/>; portal: <https://biografiasampo.fi/>, online since 2018

<sup>6</sup>National Biography of Finland: <https://kansallisbiografia.fi/>

<sup>7</sup>Information about the Sampo systems can be found here: <https://seco.cs.aalto.fi/applications/sampo/>

event-based Bio CRM [26] model, an extension of CIDOC CRM<sup>8</sup> designed for biographical data. This paper extends and complements our earlier papers on relational search using this dataset [27, 28]: here we clarify the basic concepts, present a data model including connections between two people, and present a completely reworked user interface with new options for visualizations.

The biographical data of BiographySampo is based on 13 144 biographies and includes 266 340 life events, including births, deaths, career events, received accolades, and even historical events where the persons have participated in. The life of each biographee is described semantically in terms of spatio-temporal events which they participated in. The event data was extracted from the semi-structured summaries included in the biographies using regular expressions. [24] BiographySampo has also been enriched from other data sources, such as the HISTO<sup>9</sup> ontology of Finnish historical events, and open data of the Finnish National Gallery. These events can create various types of connections between persons and other persons or places. For example two people might have been born in the same place or participated in the same historical event.

## 2. Finding and Explaining Semantic Relations

While the graph-based methods above make use of generic graph traversal algorithms that are application domain agnostic, our method uses a *knowledge-based* approach where the problem of relational search is reduced into a search problem on explained connections in a simpler search space that is transformed from the original KG using knowledge-based SPARQL CONSTRUCT query rules. The re-formulated search problem is then solved effectively as a faceted search problem [28] re-using ready-to-use tools [29, 30] for the purpose. In this way 1) non-sense connections between the query resources can be ruled out effectively by the knowledge-based rules, and 2) the explanation patterns can be used for creating natural language explanations for the connections. However, in this method the transformation rules and their explanation patterns need to be crafted manually, based on application domain knowledge.

Below is an example of a CONSTRUCT QUERY used to create Relation instances. The query<sup>10</sup> finds pairs of two people who have both participated in the same historical event, and creates instances of the Relation class that have those two people as the endpoints of the directed connection: the relationSubject and the relationObject. It also creates a human readable explanation of the relation as the label of the Relation instance. The explanation is based on a simple form where names of the people in question are placed. An example of an Finnish language explanation generated is “Rentola, Rauha ja Larkka, Erkki osallistui samaan historialliseen tapahtumaan: Suomen ensimmäinen julkinen televisiolähetys”, which can be translated as “Rentola, Rauha and Larkka, Erkki took part in the same historical event: the first public television broadcast in Finland”. There are 1934 distinct Relation instances created by this query. It is good to note that because the connections are directed, essentially the same connections are extracted twice so that both persons are the starting point of the connection once. The queries are not too computationally demanding, and executing queries like the one

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<sup>8</sup><http://cidoc-crm.org>

<sup>9</sup><https://seco.cs.aalto.fi/ontologies/histo/>

<sup>10</sup>You can test the query using the Yasgui editor [31] at: <https://api.triplydb.com/s/26heADfdBT>.

below usually only takes a couple of seconds. The example given here is a minimal one. The Relation instances can also include semantic information about, for example, times and sources of the connections.

```
PREFIX bioc: <http://ldf.fi/schema/bioc/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX skosxl: <http://www.w3.org/2008/05/skos-xl#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX nbf: <http://ldf.fi/nbf/>
PREFIX rel: <http://ldf.fi/schema/relations/>
CONSTRUCT {
  [] a rel:Relation ;
    rel:relationSubject ?person_A ;
    rel:relationObject ?person_B ;
    rdfs: ?description ;
    rel:relationType rel:sharedEvent .
}
WHERE {
  # Select historical events in BiographySampo data
  ?event a nbf:Event .
  # Select two different persons participating in the event
  ?event bioc:inheres_in ?person_A .
  ?event bioc:inheres_in ?person_B .
  FILTER (?person_A != ?person_B)
  # Get the names of the persons and the description of the event
  ?event skos:prefLabel ?event_label .
  ?person_A ^foaf:focus/skosxl:prefLabel/skos:prefLabel ?A_label .
  ?person_B ^foaf:focus/skosxl:prefLabel/skos:prefLabel ?B_label .
  # Create a description of the connection using a template
  BIND(CONCAT(CONCAT(CONCAT(CONCAT(?A_label, ' ja '), ?B_label),
    ' osallistuvat samaan historialliseen tapahtumaan: '), ?event_label) AS ?description)
}
```

### 3. Faceted Search User Interface

To search, filter, and visualize the connections, we use a web application based on faceted search. The Relation instances and the ontologies relating to the people and places are served from an RDF triple store, and queried by the application using SPARQL. We have published a demo for searching connections between people and places as part of the BiographySampo portal<sup>11</sup>. This application was implemented using the SPARQL Faceter tool [29], and is partially documented in [28]. We are now working on a more general case where an application could be used to find connections between two people or groups of people. We are initially working on only Finnish persons from the BiographySampo KG, but we are planning to include international data as well from other European countries as part of the EU project InTaVia: In/Tangible European Heritage<sup>12</sup>. The new web application with expanded functions is based on the Sampo-UI framework [30], and we plan to publish the new application later in 2023. The user interface examples in this paper are created using the new web application. While the application is not yet available online, the source code can be examined at Github<sup>13</sup>.

In this application the properties of the endpoints of the connection, and of the connection itself, are presented as facets. User can then make selections from the facets to narrow down the search to an interesting set of connections. Figure 1 shows an example of the user interface.

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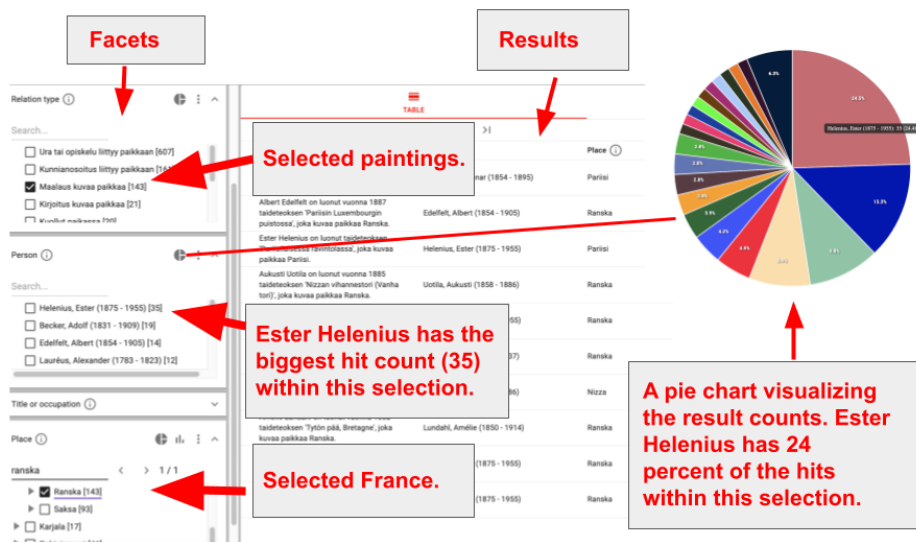
<sup>11</sup><http://biografiasampo.fi/yhteyshaku/>

<sup>12</sup><https://intavia.eu/>

<sup>13</sup><https://github.com/SemanticComputing/intaviasampo-web-app>

The facets are located on the left side of the screen and the human readable explanations of each relation are shown on the right, as well as relevant links to the entities of the relation. The user can simply select a single entity, a place, or a person, from a facet, and then look at the various relations that the selected entity has to other entities. The user can, however, also search for relations between larger groups. For example, by making a selection from the “Occupation” facet the user is shown all relations where the person has a certain occupation or any occupation in a larger category of occupations. Similarly, the place facet is hierarchical, so that the user can search for a larger area than an individual place that is directly part of the connection. For example user can select Italy, and get connections for Rome, Subiaco, and other places in Italy.

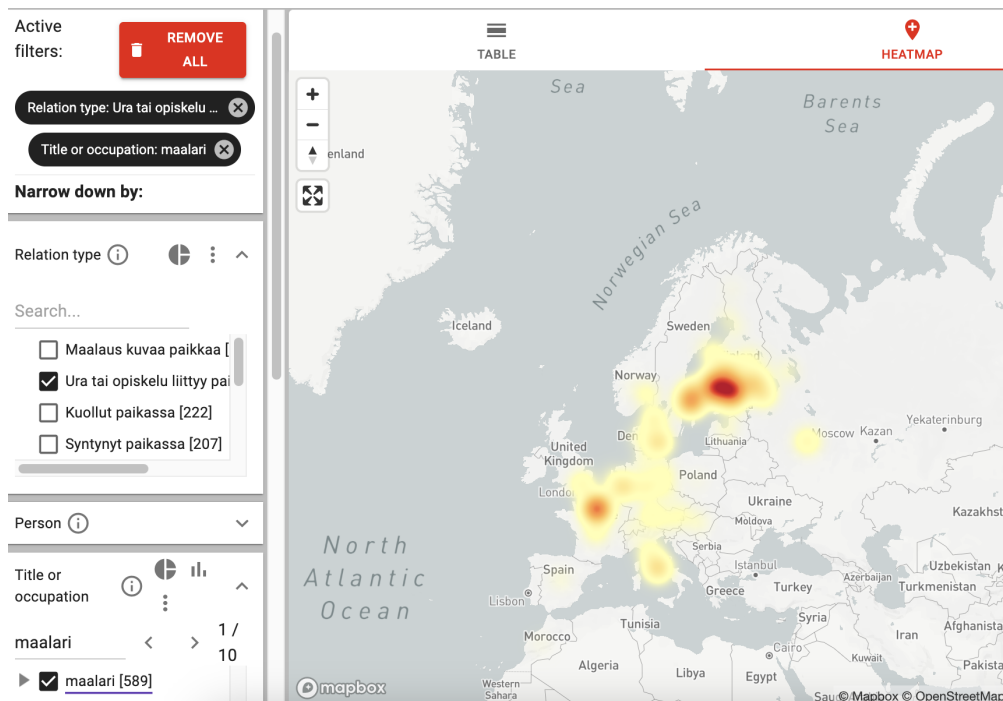
In faceted search, the hit counts of facet categories tell the quantitative distributions of the results along the facet categories. The results can be ordered and visualized based on the hit count within the facet. This feature can be used for solving some quantitative research problems. For example, Figure 1 illustrates how the question “Who created most paintings depicting France” can be solved by selecting the connection type “Painting depicts a place” (In Finnish: “Maalaus kuvaa paikkaa”) on the relationtype facet at the top, and “France” (In Finnish: “Ranska”, including the cities, such as Paris) on the Place facet at the bottom. The results are automatically ordered on the Person facet based on hit count, so the user can immediately see that the female painter Ester Helenius has the most paintings of France in the available data, with 35 paintings of the total of 143 paintings that depict France. By hitting a chart button on the people facet, the user can also visualize the distribution of hits as a pie chart..



**Figure 1:** Example of using the user interface. Solving the problem: who created most paintings depicting France?

The results can also be visualized in various other ways. For example, the relations with dates can be visualized on a timeline. For relations involving places it can be natural to use map-based

visualizations, such as heatmaps, as the place concepts of the connections have coordinates attached to them. This makes it easy to draw them on a map within the web application, using modern map services, such as Mapbox and OpenStreetMap. For example, in Figure 2 the user has selected “Career or education event is connected to a place” (“Ura tai opiskelu liittyy paikkaan”) from the relation type facet and “Painter” (“maalari”) from the occupation facet. The user has then switched the result view to “HEATMAP”. It is easy to see that most of the career and education events of Finnish painters are concentrated around Finland as would be expected. However, there are also lots of events in Western Europe in Italy, Germany, and especially France, where many prominent Finnish painters studied. In contrast, there are considerably less connections to Eastern Europe. By switching back to the default results view, the user can look at the human readable explanations of the connections, and quickly see that, for example, the connections to France are often about art studies in Paris. By selecting “Painting depicts a place” option from the relation type facet instead, it is easy to see that the paintings by Finnish painters also often depict France, Germany, and Italy, but rarely places in Eastern Europe.



**Figure 2:** Example of using a map visualization: How are the career and education events of Finnish painters spread around Europe?

#### 4. Discussion and future work

While finding single connections and their explanations between two entities are interesting, also connections between larger categories of people and geographical areas are of interest



and can be found and illustrated through faceted search and visualizations. The larger sets of connections can be seen through ontologies connected to the entities, such as occupation and place ontologies with hierarchies. We used only connections between people and places in our earlier demonstrator [28], because this is a simple case to start with. Working on connections between persons offers new challenges. The challenges addressed in this paper are twofold: 1) How to define relations so that their number stays manageable for faceted search, which can be resource consuming if the number of searched entities is large. 2) How to implement the faceted search user interface.

When searching connections between different types of entities like people and places, it is easy for the user to understand which properties in the faceted search are related to which entity of the connection. For example, when searching for connections between people and places, it is obvious that the occupation facet references the person in the connection. This is more complicated when both entities are of the same type, such as two people. The reason we use directed connections is that it makes it possible to create separate facets for both endpoints of the connection, even when they are of the same type. The user can then search for, for example, the connections between artists and writers in the KG. The drawback of this is that the connections need to be created twice so that both persons are the subject and object in one relation instance, even when the connection is fundamentally the same. This can be confusing for the user, and it creates double the number of Relation instances which slows down the faceted search.

This paper presented first results on creating a demonstrator for searching connections between persons which is first applied to the BiographySampo KG, and then extended to use international data from biographies from other European countries. We are also working on applying the approach to other cases, such as the artist data of the Getty Union List of Artist Names (ULAN)<sup>14</sup> KG.

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<sup>15</sup><https://intavia.eu/>

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