Combining Faceted Search with Data-analytic Visualizations on Top of a SPARQL Endpoint

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Abstract. This paper discusses practical experiences on creating data-analytic visualizations in a browser, on top of a SPARQL endpoint based on results of faceted search. Four use cases related to Digital Humanities research in proposography are discussed in which the SPARQL Faceter tool was used and extended in different ways. The Faceter tool allows the user to select a group of people with shared properties, e.g., people with the same place of birth, gender, profession, or employer. The filtered data can then be visualized, e.g., as column charts, with business graphics, sankey diagrams, or on a map. The use cases examine the potential of visualization as well as automated knowledge discovery in Digital Humanities research.

Keywords: Linked Data, Visualization, Biography, Prosopography, Knowledge Discovery

1 Client-side Faceted Search on a SPARQL Endpoint

Faceted search and browsing [1,12], known also as view-based search [10] and dynamic hierarchies [11], has become a norm in web applications. The idea here is to index data items along orthogonal category hierarchies, i.e., facets [4] (e.g., places, times, document types etc.) and use them for searching and browsing: the user selects in free order categories on facets, and the data items included in the selected categories are considered search results. After each selection, a count is computed for each category showing the number of results, if the user next makes that selection. In this way, search is guided by avoiding annoying ”no hits” results. Moreover, hit distributions on facets provide the end-user with data-analytic views on what kind of items there are in the underlying database. Faceted search is especially useful on the Semantic Web where hierarchical ontologies used for data annotation provide a natural basis for facets, and reasoning can be used for mapping heterogeneous data to facets [2]. The idea of combining faceted search and visualizations has been applied, e.g., in ePistolarium[5]. However, this application is not based on Linked Data unlike ours [3,4,8,9].

[4] The idea of facets dates back to the Colon Classification system of S. R. Ranganathan in library science, published in 1933.

[5] http://ckcc.huygens.knaw.nl/epistolarium/

Faceted search can be implemented with server-side solutions, such as Solr[6], Sphinx[7], and ElasticSearch[8], and higher level tools, such as vuFind[9]. However there is a lack of light-weight client-side faceted search tools or components that are able to search large datasets directly from a SPARQL endpoint. Such a tool is useful, because it can be used easily on virtually any open SPARQL endpoint on the web without any need for server side programming and access rights. This paper presents such a tool, SPARQL Faceter, a web component for implementing faceted search applications efficiently in a browser, based only on a standard SPARQL API. We extend our earlier short paper of the tool [6] by 1) showing in more detail how the tool is used and works, by 2) explaining novelties in its latest version, and 3) especially show how the tool and faceted search can be extended with different kind of data-analytic visualizations.

As a proof of concept, four use case studies of data visualization are discussed from a SPARQL Faceter perspective: 1) WarSampo, using cultural heritage materials of World War II in Finland [3]. 2) Norssit, on top of a Finnish high school alumni registry data [4]. 3) Semantic National Biography of Finland, based on the National biography of the Finnish literature society [8]. 4) U.S. Congress Prosopographer, utilizing biographical records of U.S. Congress legislators [9]. In these cases, the following two-step prosopographical research method [13, p. 47] is supported where the goal is to find out some kind of commonness or average in selected *target groups* of people. First, a target group of people is selected that share desired characteristics for solving the research question at hand. Second, the target group is analyzed, and possibly compared with other groups, in order to solve the research question. For finding target groups, faceted search is used, and then visualizations are created in order to analyze their characteristics.

The rest of the paper is organized as follows. First, characteristics of SPARQL Faceter are explained with a focus on showing how it is used in practice in applications. After this, extending the tool with visuliazations is in focus. In conclusion, lessons learned and directions for further research are discussed.

2 Using and Extending SPARQL Faceter

SPARQL Faceter uses AngularJS[10] as the implementation framework. The GitHub page[11] gives instructions how to install it, and how to define the application with facets of desired type in the source code. A couple of demo examples with queries to DBpedia and WarSampo databases are provided. It can be adopted to any Linked Data publication by configuring the endpoint, property paths for facets, and queries. The SPARQL Faceter is documented in detail[12].

[6] http://lucene.apache.org/solr/

[7] http://sphinxsearch.com/blog/2013/06/21/faceted-search-with-sphinx/

[8] https://www.elastic.co/

[9] https://vufind.org/

[10] https://angularjs.org/

[11] https://github.com/SemanticComputing/angular-semantic-faceted-search

[12] http://semanticcomputing.github.io/angular-semantic-faceted-search/#/api

The data used in our applications are available as linked open data at the Linked Data Finland platform[13] for automated data publishing. Through this platform, the data is available for analyzing textual data as well as for creating semantic annotations (semi-) automatically by using data curation tools, e.g., SAHA.[14]

```
PREFIX rdf:     <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs:    <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd:     <http://www.w3.org/2001/XMLSchema#>
PREFIX bioc:    <http://ldf.fi/schema/bioc/>
PREFIX rdfs:    <http://www.w3.org/2000/01/rdf-schema#>
PREFIX schema:  <http://schema.org/>
PREFIX skos:    <http://www.w3.org/2004/02/skos/core#>
PREFIX skosxl:  <http://www.w3.org/2008/05/skos-xl#>
PREFIX nbf:     <http://ldf.fi/nbf/>
PREFIX gvp:     <http://vocab.getty.edu/ontology#>
PREFIX crm:     <http://www.cidoc-crm.org/cidoc-crm/>
PREFIX rdf:     <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
PREFIX gvp:     <http://vocab.getty.edu/ontology#>

SELECT DISTINCT (?id AS ?id__uri) ?id__name ?value WHERE {
  # Restraints set in Faceter
  { ?id a <http://ldf.fi/nbf/PersonConcept> .
    ?id <http://xmlns.com/foaf/0.1/focus>/^<http://www.cidoc-crm.org/cidoc-crm/P98_brought_into_life>/
        <http://ldf.fi/nbf/time>/<http://vocab.getty.edu/ontology#estStart> ?slider_2 .
    FILTER (1800<=year(?slider_2) && year(?slider_2)<=2018)
    }

  # Query person's age
  ?id foaf:focus/^crm:P100_was_death_of/nbf:time [ gvp:estStart ?time ; gvp:estEnd ?time2 ] ;
      foaf:focus/^crm:P98_brought_into_life/nbf:time [ gvp:estStart ?birth ; gvp:estEnd ?birth2 ] .
  BIND (xsd:integer(0.5*(year(?time)+year(?time2)-year(?birth)-year(?birth2))) AS ?value)
  # Filter out erroneous cases
  FILTER (-1<?value && ?value<120)

  # Query for person's name
  ?id skosxl:prefLabel ?id__label .
  OPTIONAL { ?id__label schema:familyName ?id__fname }
  OPTIONAL { ?id__label schema:givenName ?id__gname }
  BIND (CONCAT(COALESCE(?id__gname, "")," ",COALESCE(?id__fname, "")) AS ?id__name)

} ORDER BY ?value ?id__fname ?id__gname
```

Fig. 1. A SPARQL example for querying people's ages

Figure 1 depicts a SPARQL query for fetching the data visualized in Fig. 2. The first block in the query pattern defines the restricted target group of the Faceter application, in this case we are interested people who were born on or after the year 1800, a choice that has been made with the timespan slider. The example follows the data model of the National Biography of Finland [8], so to query for the desired resource in the data, property paths are utilized. In the next block related events of birth are searched, and the age of a person is calculated. Possible errors in the data are filtered out by accepting only values in the range of 0 to 120 years. In the third block, the person's proper name is constructed. Some of the fields are optional, because due to the data, we cannot assume all the person entries to have both the first and the family names. The query returns JSON formatted array consisting of objects containing the URI of the resource, the person name, and age. In the application the data is converted to a JavaScript array

[13] http://ldf.fi

[14] http://demo.seco.tkk.fi/saha

suitable as input for, e.g., Google Chart tools[15], or Google Maps[16]. The output in this example case, (Fig. 2) is a column chart with age on the horizontal, and the amount of people on the vertical axis. A mouse click on any of the columns shows a modal list of all people having that age.

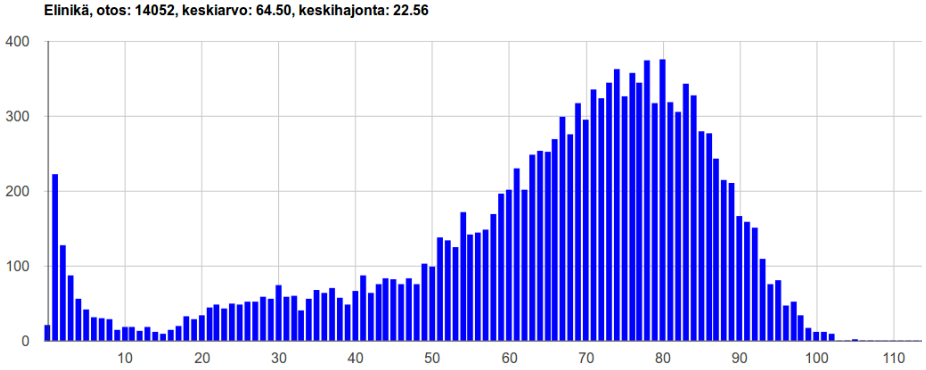


Fig. 2. Lifespan of people lived in 1800–2018

3 Applications

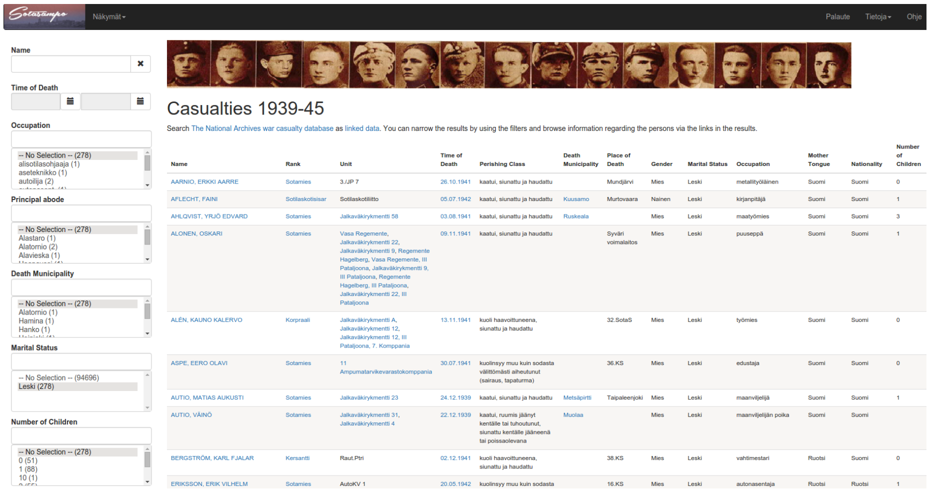
In this section examples of visualizations on top of the SPARQL Faceter tool in different applications are shown and discussed.
is the first semantic portal for serving and publishing large heterogeneous sets of linked open data about the World War II (WW2)[17]. To create a global view of the war, and to attain a deeper understanding of its history, the portal contains. e.g., some 95 000 death records of WW2 casualties. This in-use portal includes 8 different application perspectives through different datasets, and had 130 000 users in 2017.

Fig. 3 shows a screenshot of the faceted search application in the casualties perspective. The data is laid out in a table-like view. Facets are presented on the left of the interface with string search support. The number of hits on each facet is calculated dynamically and shown to the user, and selections leading to an empty result set are hidden. In Fig. 3, seven facets and the results are shown, where the user has selected “widow” in the marital status facet, focusing the search down to 278 killed widows that are presented in the table with links to further information.

The faceted search is used not only for searching but also as a flexible tool for researching the underlying data. In Fig. 3, the hit counts immediately show distributions

[15] https://developers.google.com/chart/
[16] https://cloud.google.com/maps-platform/
[17] https://www.sotasampo.fi/en/

of the killed widows along the facet categories. For example, the facet "Number of children" shows that one of the deceased had 10 children and most often (in 88 cases) widows had one child. If we next select the category "one child" on its facet, we can see that two of the deceased are women and 86 are men in the gender facet. In the latest version of SPARQL Faceter, each facet component has a push button for visualizing the distributions with Google pie charts.



Name

Time of Death

Occupation

-- No Selection -- (278)
alisotilasohjaaja (1)
aseteknikko (1)
autoilija (2)

Principal abode

-- No Selection -- (278)
Alastaro (1)
Alatornio (2)
Alavieska (1)

Death Municipality

-- No Selection -- (278)
Alatornio (1)
Hamina (1)
Hanko (1)

Marital Status

-- No Selection -- (94696)
Leski (278)

Number of Children

-- No Selection -- (278)
0 (51)
1 (88)
10 (1)

Casualties 1939-45

Search The National Archives war casualty database as linked data. You can narrow the results by using the filters and browse information regarding the persons via the links in the results.

Name	Rank	Unit	Time of Death	Perishing Class	Death Municipality	Place of Death	Gender	Marital Status	Occupation	Mother Tongue	Nationality	Number of Children
AARNIO, ERKKI AARRE	Sotamies	3./JP 7	26.10.1941	kaatui, siunattu ja haudattu		Mundjärvi	Mies	Leski	metallityöläinen	Suomi	Suomi	0
AFLECHT, FAINI	Sotilaskotisisar	Sotilaskotiliitto	05.07.1942	kaatui, siunattu ja haudattu	Kuusamo	Murtovaara	Nainen	Leski	kirjanpitäjä	Suomi	Suomi	1
AHLQVIST, YRJÖ EDVARD	Sotamies	Jalkaväkirykmentti 58	03.08.1941	kaatui, siunattu ja haudattu	Ruskeala		Mies	Leski	maatyömies	Suomi	Suomi	3
ALONEN, OSKARI	Sotamies	Vasa Regemente, Jalkaväkirykmentti 22, Jalkaväkirykmentti 9, Regemente Hagelberg, Vasa Regemente, III Pataljoona, Jalkaväkirykmentti 9, III Pataljoona, Regemente Hagelberg, III Pataljoona, Jalkaväkirykmentti 22, III Pataljoona	09.11.1941	kaatui, siunattu ja haudattu		Syväri voimalaitos	Mies	Leski	puuseppä	Suomi	Suomi	1
ALÉN, KAUNO KALERVO	Korpraali	Jalkaväkirykmentti A, Jalkaväkirykmentti 12, Jalkaväkirykmentti 12, III Pataljoona, 7. Komppania	13.11.1941	kuoli haavoittuneena, siunattu ja haudattu		32.SotaS	Mies	Leski	työmies	Suomi	Suomi	0
ASPE, EERO OLAVI	Sotamies	11 Ampumatarvikevarastokomppania	30.07.1941	kuolinsyy muu kuin sodasta välittömästi aiheutunut (sairaus, tapaturma)		36.KS	Mies	Leski	edustaja	Suomi	Suomi	0
AUTIO, MATIAS AUKUSTI	Sotamies	Jalkaväkirykmentti 23	24.12.1939	kaatui, siunattu ja haudattu	Metsäpirtti	Taipaleenjoki	Mies	Leski	maanviljelijä	Suomi	Suomi	1
AUTIO, VÄINÖ	Sotamies	Jalkaväkirykmentti 31, Jalkaväkirykmentti 4	22.12.1939	kaatui, ruumis jäänyt kentälle tai tuhoutunut, siunattu kentälle jääneenä tai poissaolevana	Muolaa		Mies	Leski	maanviljelijän poika	Suomi	Suomi	
BERGSTRÖM, KARL FJALAR	Kersantti	Raut.Ptri	02.12.1941	kuoli haavoittuneena, siunattu ja haudattu		38.KS	Mies	Leski	vahtimestari	Ruotsi	Suomi	0
ERIKSSON, ERIK VILHELM	Sotamies	AutoKV 1	20.05.1942	kuolinsyy muu kuin sodasta		16.KS	Mies	Leski	autonasentaja	Ruotsi	Ruotsi	1

Fig. 3. The faceted search interface of death records with one selected facet. The left side contains the facets, displaying available categories and the amount of death records for each casualty. Death records matching the current facet selections are shown as a table.

2) Norssit dataset consists of a register with over 10 000 alumni of the prominent Finnish high school "Norssi" in 1867–1992. The register was transformed into RDF, was enriched by data linking, was published as a linked data service, and is provided to end users via a faceted search engine and browser for studying lives of historical persons and for prosopographical research. [4]

The Norssit portal[18] contains two pages of visualizations[19]. The pages use Google Charts showing search results as pie or column charts or sankey diagrams [7]. An example of rendering the most common employers on different decades is depicted in Fig. 4.

3) Semantic National Biography of Finland The National Biography of the Finland[20] consists of biographies of notable Finnish people throughout history. The biographies describe the lives and achievements of historical figures, containing vast amounts

[18] http://www.norssit.fi/semweb

[19] http://www.norssit.fi/semweb/#!/visualisointi,http://www.norssit.fi/semweb/#!/visualisointi2

[20] http://kansallisbiografia.fi

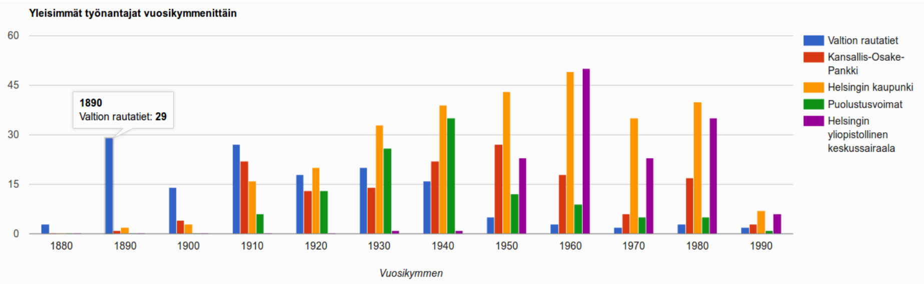


Fig. 4. Column chart showing the most common employers and their changes in time.

of references to notable Finnish and foreign figures, including internal links to other biographies. [5]

To support the prosopographical research, the portal contains pages with faceted search where the data is visualized on Google Maps, or as column charts [7]. An example of rendering the query results on Google Maps is depicted in Fig. 5. The portal also has a faceted search page for linguistic analysis of the vocabulary used in biographical descriptions.

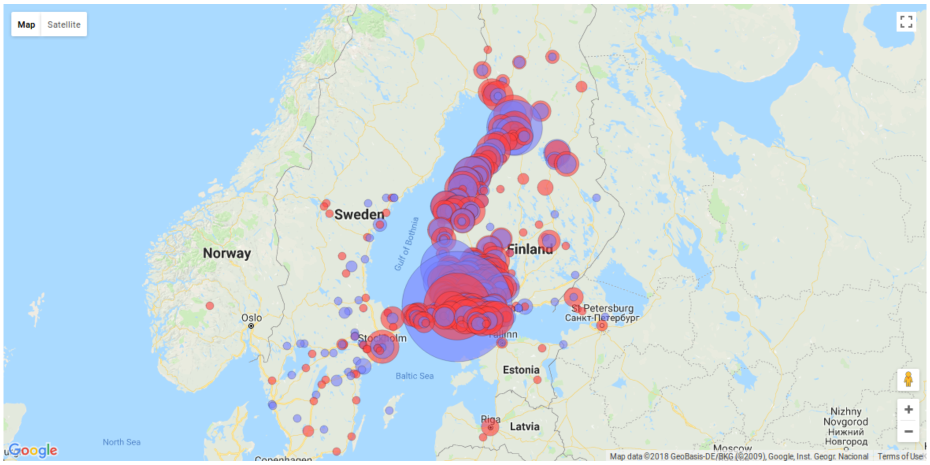


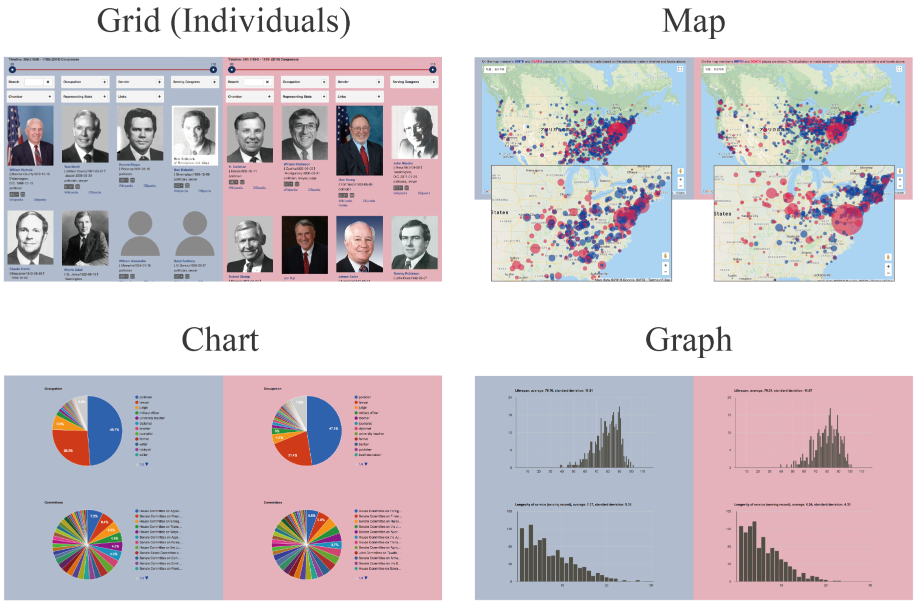
Fig. 5. Places of birth and death of 17th century Finnish clergy

4) U.S. Congress Prosopographer This interface[21] contains biographical records of 11 987 persons who served in the U.S. Congresses from the 1st (1789) to the 115th

[21] https://semanticcomputing.github.io/congress-legislators/

(2018) one—converted and extracted from open-source data[22,23]. The interface contains four integrated tools and demonstrates how historical patterns correspond to biographical information and further intertwine with politics, economics, and historical knowledge alongside the American history.

Being adapted from the previous studies above, a novelty of this interface are the comparing visualizations. As shown in Fig. 6, a different set of target groups—in this case, the two major parties, Democrats and Republicans—can be analyzed and compared with each-other. The end user is able to find and execute new insights through the independent variables, as well as the latent biographical relationship of U.S. Congress legislators through selecting, filtering, and comparing two different accounts of histories.


Grid (Individuals)

Map

Chart

Graph

Fig. 6. Examples of Comparing Visualizations: Democratic (left) / Republican (right)

4 Discussion

Based on the applications discussed, faceted search and browsing can be combined in a useful way with various means and tools for visualization: facet selections are a

[22] https://github.com/unitedstates/congress-legislators

[23] http://k7moa.com

very flexible way to filter out result sets, and we have demonstrated that this can be done in real time using SPARQL queries in endpoints containing tens of millions of triples. Based on the query results, wrappers for data visualization tools, such as Google Charts for statistics or network analysis tools can be integrated and reused easily. By making the data analysis on the client side, computational burden can be distributed to end-user browsers, and Rich Internet Applications can be created without server-side programming. Moreover, the resulting visualizations open up ways of exploring new types of questions, and further evokes a knowledge discovery process in conducting digital humanities research.

A key challenge in this approach is how to deal with large result sets. It is usually not feasible to transfer very large result sets, say tens of thousands of casualty records in the WarSampo case, from the server to the browser. If the data is not available in the browser, it cannot of course be analyzed there. This problem is solved in SPARQL Faceter by paginating the results; the results are uploaded in pages and only when needed. The end-user should be aware about the limitation that the visualizations are based on only the data that has been uploaded. The size of the page therefore sets a limit on how large datasets can be visualized, even though very large result datasets can be queried on the server side.

The use case study WarSampo was implemented by the original SPARQL Faceter [6] while the other use cases discussed are based on its new versions with the following enhancements: 1) Every facet is now able to make its own SPARQL query (or many), which leads to better efficiency. 2) Hierarchical facets up to any number of levels are supported and more efficiently implemented. 3) Text search facet is included as a new facet type. 4) A slider facet for selecting a range of numerical values interactively can be used. 5) Facet hit distributions can be visualized using pie charts in addition to hit counts. There are also some enhancements made for visualizations. The U.S. Congress Prosopographer allows, for example, visual comparison of two groups, a functionality that should also be implemented to our ongoing project of Semantic National Biography. The different Faceter versions and extensions need to be amalgamated together in next versions of the tool and applications. Also the technical solutions for showing new types of visualization, such as social networks of people should be studied more. Still another direction for further work are the aesthetic qualities. The visualizations are generated using standardized templates, e.g., web frameworks such as Google Charts, and balancing between usability and design aesthetics needs to be studied.

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[24] http://seco.cs.aalto.fi/projects/severi

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