

Linked Data Brokering Service for Historical Places and Maps

Eero Hyvönen, Esko Ikkala, and Jouni Tuominen

Semantic Computing Research Group (SeCo), Aalto University, Finland
<http://seco.cs.aalto.fi/>, firstname.lastname@aalto.fi

Abstract. This paper presents a new Linked Open Data brokering service model HIPLA for using and maintaining historical place gazetteers and maps based on distributed SPARQL endpoints. The model introduces several novelties: First, the service facilitates collaborative maintenance of geo-ontologies and maps in real time as a side effect of annotating contents in legacy cataloging systems. The idea is to support a collaborative ecosystem of curators that creates and maintains data about historical places and maps in a sustainable way. Second, in order to foster understanding of historical places, the places can be provided on both modern and historical maps, and with additional contextual Linked Data attached. Third, since data about historical places is typically maintained by different authorities and in different countries, the service can be used and extended in a federated fashion, by including new distributed SPARQL endpoints (or other web services with a suitable API) into the system. To test and demonstrate the model, we created the first prototype implementation Hipla.fi of the HIPLA model. Hipla.fi is based on four Finnish datasets in SPARQL endpoints totaling some 840,000 geocoded places on 450 historical maps from two atlas series aligned on modern maps, and on the Getty Thesaurus of Geographic Names (TGN) SPARQL endpoint in the US. As a first application, a part of the Hipla.fi data service has been applied in creating a 5 million triple semantic portal of historical Second World War data with tens of thousands of end users.

1 Challenges of Managing Historical Place Gazetteers

Linked Data publishing principles [4] and geospatial place ontologies [1] are becoming popular in georeferencing [5], i.e., in relating information to geographic locations in information sciences. Ontologies define classes and individuals for representing geographic regions, their properties, and mutual topological and other relationships. Interoperability of dataset contents in terms of geographical places can be fostered by sharing place resource URIs in different applications, preferably already when cataloging and annotating data.

There are lots of databases and repositories available for contemporary places provided by national land survey organizations and international consortia. For example, GEOnet Names Server¹ is the official repository of standard spellings of foreign geographic names, sanctioned by the United States Board on Geographic Names (US

¹ <http://geonames.nga.mil/gns/html/>

BGN). GeoNames² is an international initiative whose database contains over eight million place names harvested from tens of local databases, and there is also an interactive Web 2.0 interface for the developer community for adding new missing places.

Dealing with historical geographical places and gazetteers³ [12] adds a temporal dimension and the notion of change to Geographic Information Systems (GIS). Many, if not most, historical places, such as Carthago or Czechoslovakia, do not exist anymore on modern maps or have at least changed substantially over the time. A place name may refer to different versions of the places depending on the time [9]. For example, Germany in 1943, 1968, and today covers quite different regions, and the question of what Germany actually was in the 18th and 19th century may be vague. As a result, creating and managing historical place ontologies has several special challenges when compared to contemporary gazetteers, including the following:

1. **Contextualizing Historical Place Names.** Understanding a historical place requires more contextual data than a contemporary one. Not only are the names ambiguous, but even "same" places can have different properties in different times (e.g., "Germany" above).
2. **Need for Historical Maps.** Historical places cannot necessarily be found on modern maps, but only on old historical maps from a matching time period that provides an essential context for the places.
3. **Maintaining Evolving Historical Gazetteers.** Historical places cannot be listed comprehensively, but new place names are encountered constantly in cataloging, and as time goes and the world evolves. Dynamic and fast mechanisms for ontology updates and sharing them are needed. The situation is more dynamic in historical than in modern gazetteers that can be completed more easily at a fixed point in time.
4. **Managing Distributed Historical Gazetteers.** Data about historical places are often distributed across different contemporary countries, whose data is managed by national institutions. Data from several organizational data silos are usually needed to cover larger areas (say the Roman Empire), and on the other hand, these organizations often maintain overlapping registries of the same places. More cross-organizational collaboration is needed when dealing with historical gazetteers than with contemporary ones. Since there are several strong independent gazetteer authorities in the field, one has to deal with different identifiers, data models, and distributed data stores that evolve independently in different locations.

This paper presents a new Linked (Open) Data (LOD) broker service model for historical places and maps, called HIPLA, addressing these challenges. The service model is based on a set of distributed SPARQL endpoints. HIPLA is essentially a federated ontology service [2,14] for historical places where the historical context of places can be presented to the end user for disambiguating place names and understanding them in context and on historical maps. A novelty of HIPLA is its collaborative real-time mechanism for updating and maintaining evolving ontologies of historical places, based on providing the community with yet another SPARQL endpoint of suggested new place

² <http://geonames.org>

³ A gazetteer is a geographical dictionary or directory used in conjunction with a map or an atlas.

resources. This data source can be updated in real time for sharing new resources within the community, and be finally integrated into the underlying main ontologies. Our ultimate goal is to integrate the HIPLA service model into legacy cataloging workflows, which facilitates a sustainable model for aggregating historical place names in shared data repositories as time goes by.

We present the HIPLA model using its prototype implementation Hipla.fi for illustrating the more general underlying ideas. Hipla.fi is a Rich Internet Application (RIA) service on top of distributed SPARQL endpoints. As an application use case, the Hipla.fi data service has been applied in creating a semantic portal for Second World War Data [10] dealing with places in pre-war and contemporary Finland, many of which do not exist on after-war maps, since they were destroyed or renamed after annexed to the Soviet Union in the Paris Peace Treaties in 1947. The paper extends our earlier papers [8,11] by making a clear distinction between the general brokering model HIPLA and its realization Hipla.fi that is also applied in an in-use semantic portal application.

In the following, we first describe the HIPLA model and the Hipla.fi implementation of it. After this, the cataloging process using evolving shared ontologies is in focus, followed by a discussion of Linked Data services, and an application case of a war history portal. In conclusion, related works are discussed and contributions of the paper are related to them, regarding the research challenges 1–4 above.

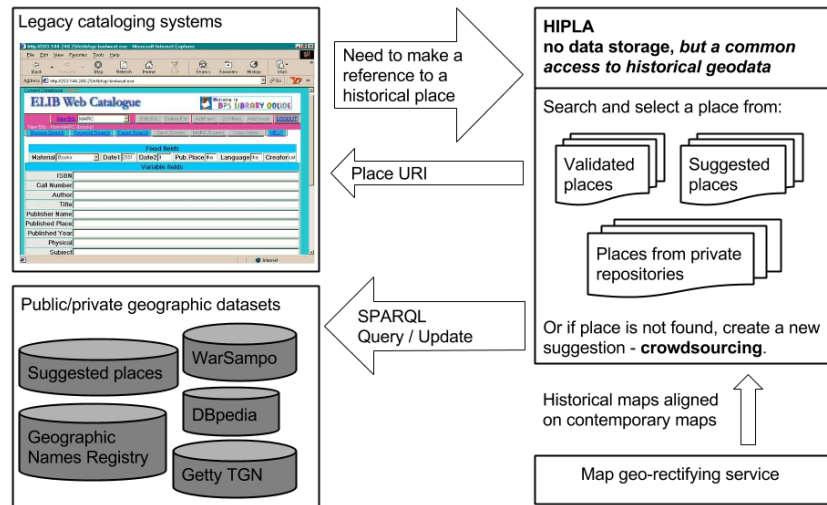


Fig. 1. HIPLA system architecture.

2 HIPLA Service Model

The end users of HIPLA are 1) collaborative geo-ontology developers, 2) catalogers of historical content, 3) information searchers, and 4) application developers. For group 1

HIPLA facilitates a sustainable model for aggregating historical place names in shared data repositories as time goes by. For groups 2 and 3 HIPLA provides a combination of historical and contemporary maps, linked contextual data, and semantic federated search to find and understand historical places. User group 4 can utilize distributed SPARQL endpoints, URI resolving services, and an autocompletion text search widget

Fig. 1 depicts the components of the HIPLA service model. In the left lower corner are the public SPARQL endpoints (PSE) hosting the historical place gazetteers connected to the service, such as TGN, DBpedia, or national land survey gazetteers. Above it is a legacy cataloging or annotating system where references to historical places need to be made. This system queries the HIPLA service in the upper right corner using, e.g., an autocompletion widget. HIPLA is a brokering service that federates the query to the PSEs and aggregates the results. In addition, HIPLA has an internal repository of Suggested New Places, and may also federate the query to private SPARQL endpoints, such as a confidential place registry of a museum. In addition, HIPLA is connected to a Map geo-rectifying service, providing historical maps on top of contemporary maps for HIPLA's end-user interface.

3 Prototype Implementation: Hipla.fi

In this section we show how the HIPLA system is used in practice, by presenting its prototype implementation Hipla.fi, publicly online at <http://hipla.fi>. Fig. 2 depicts the HIPLA user interface, providing the end user with the following functionalities:

Searching places For finding, disambiguating, and examining historical places, there is an autocompletion search input field (a). By using the checkboxes above (b) the user can select which datasets (e.g., TGN, Suggested New Places) are included in the search results. The results are grouped based on their dataset, and they can be examined as follows:

1. Hovering the cursor over the search results shows where the places are: the corresponding marker bounces on the map.
2. A click on a search result label or on the corresponding map marker opens the info window of the place, showing its context (c).
3. A click on the menu button on a result row (a) shows the place data in a Linked Data browser for investigating the data in detail.

Multiple dataset browsing If the user does not know the name of the place, but she has some idea where the place is located, she can pan and zoom the map view to the area. After this it's possible to use "View all places on current map view" button next to (b) on the left. This way places from different datasets connected to HIPLA are rendered on the map, and the user can check if the place exists already in some of the datasets. Places from different datasets are dataset-wise color-coded, which makes it possible to compare places in different gazetteers.

View on historical maps The "Maps" (b) tab provides a list of old maps that intersect the current map view. The map images are fetched from HIPLA's Map Warper georectifying service⁴ and their metadata is queried with SPARQL from the map RDF

⁴ <http://mapwarper.onki.fi>

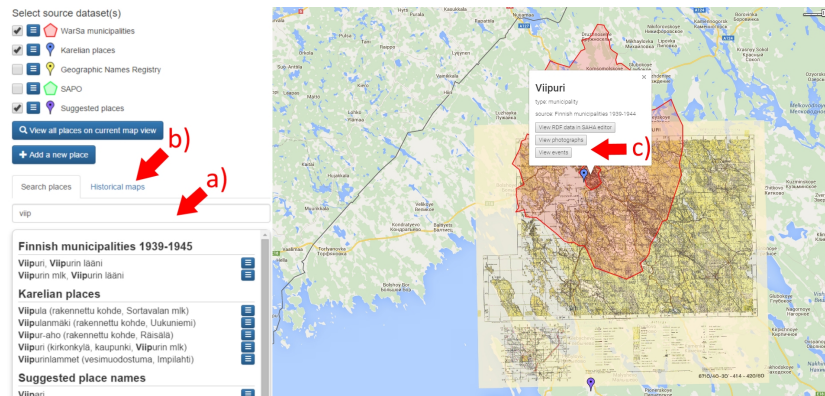


Fig. 2. Hipla.fi user interface.

graph of the HIPLA service. Each map has a checkbox for rendering the map on the main map view, a thumbnail image, information about map series, scale and type, and a link to view the map in Map Warper. All map series are visible by default, but with the map series button it is possible to filter maps series-wise. Once one or more historical maps have been selected with the checkboxes for viewing, the opacity of the historical maps can be adjusted with the slider that is located on the top right corner of the map. If the user pans or zooms the main map view, clicking on the "Refresh map list" button updates the map list.

View contextual data When the user selects a place, the resource can be browsed using the Linked Data browser SAHA⁵ to see its detailed structure. Furthermore, contextual data (c) is provided connecting the place to other relevant data sources using an infobox. This functionality was first piloted with the spatial datasets of the WarSampo portal [10], providing, e.g., 160,000 historical photos related to the places during the Second World War and a timeline of historical events.

Suggesting new place names If the place at hand does not exist in any of the datasets connected to HIPLA, the user can submit a place suggestion by clicking the "Add a new place" button and filling the place details form. Coordinates for the new place suggestion can be selected from the Google map view, and it is possible to use historical map sheets for setting the coordinates. Finally the user must select the target dataset for the place suggestion. After the "Save changes" button is clicked, the new place suggestion is available for all the users of the service.

Our first application case in developing HIPLA has been on modeling, storing, and searching Finnish place names in multiple SPARQL endpoints, and on displaying them on historical and contemporary maps at the same time. The datasets used in Hipla.fi are stored in separate RDF graphs, which makes it possible to offer dynamic selection of data sources for the user interface or external data consumers. Table 1 presents the datasets currently connected to HIPLA.

⁵ <http://seco.cs.aalto.fi/services/saha/>

Table 1. Datasets connected to Hipla.fi.

Dataset	Original source	Place type	Size
Finnish Municipalities 1939–1944	National Archives of Finland	municipality	612
Karelian map names in Finland and Russia	Jyrki Tiittanen / National Land Survey of Finland	village, house, etc.	34,938
Finnish Spatio-Temporal Ontology	SeCo research group	municipality	1261
Finnish Geographic Names Registry	National Land Survey of Finland	61 place types	797,668
The Getty Thesaurus of Geographic Names	J. Paul Getty Trust	1800 place types	2,156,896
Historical Senate atlas (ca. 1900) in 1:21 000	National Archives of Finland	map	404
Karelian maps (1928–1951) in 1:100 000	National Land Survey of Finland	map	47

New datasets can be added to the Hipla.fi service by providing their configuration to the system. The needed information include 1) the SPARQL endpoint URL, 2) a SPARQL query for the autocompletion search, and 3) a HTML template for rendering a SPARQL result in the autocompleted result list. In addition, another SPARQL query and a HTML template can be supplied for providing contextual data for the user when a place is selected.

The system was implemented using the Linked Data Finland platform⁶ [7], based on Fuseki⁷ with a Varnish Cache⁸ front end for serving the Linked Data. The end-user interface of HIPLA is a lightweight HTML5 single page map application, which provides access to multiple data sources with SPARQL queries and autocomplete search functionality using typeahead.js⁹. Embedded Google Maps view is used to visualize historical places. HIPLA's Map Warper is an instance of the open source Map Warper tool¹⁰ of the New York Public Library for georectifying old maps on modern ones.

4 Cataloging with Evolving Shared Ontologies

When annotating data using an ontology service, it is a challenge to decide what to do when a new concept is needed in a shared ontology. The cataloger needs to make a reference to a concept not present in the shared ontology, say create a new place instance. The traditional approach to maintaining a Knowledge Organization System (KOS) is to contact the committee in charge of maintaining the KOS with a suggestion

⁶ <http://www.ldf.fi>

⁷ http://jena.apache.org/documentation/serving_data/

⁸ <https://www.varnish-cache.org>

⁹ <http://twitter.github.io/typeahead.js/>

¹⁰ <https://github.com/timwaters/mapwarper>

of a new concept to be added to the system. However, the cataloger cannot wait for the committees decision for days, weeks, or months. Therefore, a shared mechanism is needed for populating the ontology with the following features: First, it should be possible for the cataloger to create a new concept in real time or she is not able to make the annotation at hand, or has to make a less accurate annotation using only the existing concepts. Second, the new concept should be shared in real time with other users. Otherwise they may end up in creating duplicates of the same concept. Third, there should be a mechanism for the maintaining committee of the KOS to edit, approve, or reject the proposed concepts afterwards, in case errors or duplicates arise.

We generalize our previously proposed ontology maintenance process [8] by supporting simultaneous usage of multiple ontologies, managed independently by different organizations. The process involves three groups of people: 1) Ontology Committees (OC) responsible for maintaining and validating the ontologies, 2) Developer Users (DU) using the system with the right to add new concept suggestions in the system, 3) Ordinary Users (OU) with the right of using the system as it is. The ontology infrastructure is divided into three parts: 1) Validated Concepts (VC) constitute the official knowledge graphs of the ontologies that have been validated and approved by the OCs. 2) Suggested Concepts (SC) constitute a graph that includes concepts proposed by the DUs, but that have not been validated by the OCs yet. 3) Concept Mappings (CM) is a graph of mappings between suggestions and accepted concepts in the VC graphs.

The ontology evolves by crowdsourcing the DUs as follows:

1. A DU searches for an annotation concept C (using, e.g., autocompletion search). The VCs and SCs are grouped into their own categories in the result listing. In this way the DU knows whether the concept is already accepted or was only suggested by someone. Both VCs and SC concepts can be used for annotation.
2. If C is found and acceptable the DU can use it and the annotation is done.
3. Otherwise, she can create a new concept C with mandatory metadata, including a persistent identifier (IRI), labels for human identification, and additional properties, such as (sub)classes, coordinates, etc., depending on the data model of the KOS. Also, the ontologies the concept should be added into are chosen in this step.
4. C is added into the SC, and is immediately available to all users. In particular, the DU is able to use C in her annotation at hand immediately.
5. The OCs validate new concepts in the SC every now and then.
6. If the new concept C is valid, the OC copies it from the SC into a VC. The OC typically mints a new URI to the concept so that it conforms to the URI policy of the ontology the concept is added into. At this point, it is possible to add and edit metadata of the concept. As the IRI of the suggested concept may have already been used by the community, it should not be removed. Instead, the OC creates a new mapping entry in the CM. A mapping entry is a triple (*suggestedIRI*, *mapping*, *validatedIRI*) where *suggestedIRI* is the suggested concept, *validatedIRI* is a concept in a VC, and *mapping* is a predicate indicating the relation between the suggested and validated concept. Typically *owl:sameAs* is used as the mapping predicate.
7. If the concept is not accepted, OC either marks it with an unaccepted status or adds a new mapping entry in the CM linking the suggested concept to an existing validated concept that should be used instead.

The idea of the CM is to give a fallback service to users who have used suggested concepts. Using the concept mappings the data already annotated with SC by a user in her database can be mapped to the validated concepts of the VCs later on.

5 Linked Data Services

The Hipla.fi data services include the publication of the suggested place names and the metadata of historical maps as Linked Data in a SPARQL endpoint, resolving URIs of the brokered data sources for end users, and an autocompletion widget for integrating the data into legacy systems.

URI Resolving of Linked Data The place names suggested by the users are published in a SPARQL endpoint hosted in the Linked Data Finland platform. The URIs of the data resources are resolved to RDF presentation for machines and HTML pages for humans. The distributed gazetteers used in the Hipla.fi as data sources are published in the Linked Data publication platforms ran by the original data owners, and used in Hipla.fi through their SPARQL endpoints. As Hipla.fi is a brokering service, the URI resolving of Linked Data of the places in the gazetteers is handled by the data owners.

Hipla.fi prototype implementation provides a URI resolving service for displaying information related to a place on a map view. The URL template for resolving a place URI is `http://hipla.fi/?uri=URI`, where URI is the identifier of a place. The resolving mechanism can be used for displaying an HTML presentation of a place for an end user for any place that is known to the Hipla.fi service, i.e., can be found in a SPARQL endpoint configured as a data source for the service.

Publishing Historical Maps We use three classes to model historical maps: 1) atlas, 2) map series, and 3) map. An atlas is a collection of maps, which may contain one or more map series. A map series is a map published over several sheets. Therefore the map sheets belonging to the same series have the same scale and cartographic specifications. The map class represents the actual map sheets. It is also possible to store an individual map sheet without using the atlas or map series class. The map series and map classes are described with common properties, e.g. scale, map type and time of issue.

The metadata of the maps including a map identifier is stored in the RDF graph of the HIPLA Service, and the Map Warper tool provides the actual map images for application use based on the map identifier.

Integration into Legacy Applications The idea is that Cultural Heritage organizations can connect their legacy cataloging systems to HIPLA using an API in the same vein as in ONKI [13], harmonizing the content created by the community. As a starting point, we have isolated the text search user interface component used in the Hipla.fi prototype into a stand-alone JavaScript widget. The widget can be integrated into a web-based cataloging system, enriching text fields with autocompletion functionalities. The URI and label of the place selected with the widget are communicated to the cataloging system via a JavaScript callback function along with information about the source dataset, e.g.,

its name and SPARQL endpoint URL. The idea is that the widget can be configured to suit different use cases, e.g., by adding organization's private repository of places as a data source, or by customizing what kind of contextual information about a place is displayed in the autocomplete search result listing (e.g., accompanied with a compact info window containing a map that shows the location of the place). We consider the autocomplete widget to be generic enough to be applied not only to historical place ontologies, but to any kind of reference ontologies (e.g., person databases and classification schemes).

6 Application Case: Semantic Portal for World War II

This section presents an application of the Hipla.fi prototype in the WarSampo Portal¹¹, a system for publishing collections of heterogeneous, distributed data about the Second World War on the Semantic Web. The WarSampo Portal allows both historians and laymen to study war history and destinies of their family members in war from different interlinked perspectives.

In this case, the Hipla.fi was populated with four data sources in SPARQL endpoints: 1) National Archives of Finland's map application data of 612 wartime municipalities, 2) the Finnish Spatio-Temporal Ontology describing the regions of the Finnish municipalities in different times¹², 3) a dataset of geocoded Karelian map names (35,000 map names with coordinates and place types), and 4) the current Finnish Geographic Names Registry (PNR) (800,000 places). In addition, some 450 historical map sheets from two atlases were rectified on modern maps.

Most datasets used in WarSampo contain references to historical places. Hipla.fi provides the application with a brokering service of historical places for 1) interlinking the WarSampo datasets and for 2) visualizing the contents of different datasets on historical and contemporary maps. Since WarSampo uses the Hipla.fi URIs in its datasets, the resolving mechanism of rendering URIs as end-user HTML pages can be utilized easily. When there is a need in WarSampo to show the user information about a place with a URI, this can be done easily by just creating the link `http://hipla.fi/?uri=URI`. For example, the place "Porkkala" can be found in the PNR dataset¹³ of the Linked Data Finland data service with the local name `P_10070203`. Its URI

```
http://ldf.fi/pnr/P_10070203
```

can be rendered in Hipla.fi by the URI:

```
http://hipla.fi/?uri=http://ldf.fi/pnr/P_10070203
```

as the HTML page depicted in Fig. 3, showing the location and related data of Porkkala. This page has similar functionalities as the Hipla.fi service described earlier. For example, Porkkala can be viewed on historical maps by using the map tab, and related photographs, events, and magazine articles can be viewed by following the links.

¹¹ Available and in use at <http://sotasampo.fi>

¹² <http://seco.cs.aalto.fi/ontologies/sapo/>

¹³ Described at <http://www.ldf.fi/dataset/pnr>

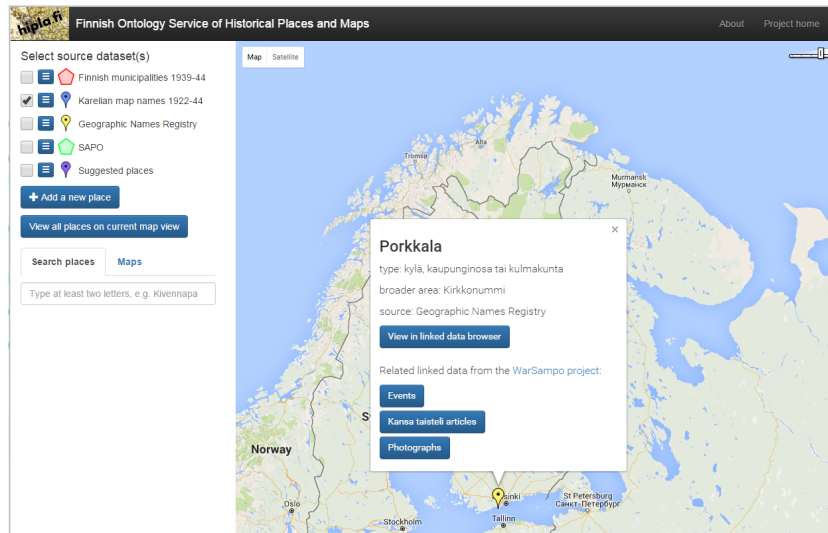


Fig. 3. A Linked Data Finland URI rendered for the end user as HTML in Hipla.fi.

7 Related Work and Discussion

This paper presented HIPLA, an ontology library service [2] model for brokering historical places from distributed LD gazetteers on historical and contemporary maps, and its prototype implementation Hipla.fi. There are several gazetteers of historical places on the web, such as The Historical Gazetteer of England’s Place-names¹⁴, Gazetteer for Scotland¹⁵, the Danish service DigDag¹⁶ for finding historical administrative areas with polygons on maps, the Dutch services Gemeentegeschiedenis.nl¹⁷ and Histopo.nl¹⁸, and the Alexandria Digital Library Gazetteer [6]. Thesauri of historical places, published as Linked Data, include the Getty TGN of some 1.5 million records and Pleiades¹⁹ [3] for ancient places. Pelagios projects²⁰ develop APIs and GUIs for multiple historical gazetteers, such as Pleiades. DBpedia²¹ contains masses of LD of historical and contemporary places while GeoNames focuses on modern places. VIAF²² brokers mutually aligned authority files, including historical place names, from various national libraries around the world in LD form, and from some additional open data sources, such as DBpedia and Wikidata.

¹⁴ <http://www.placenames.org.uk>

¹⁵ <http://www.scottish-places.info>

¹⁶ <http://www.digdag.dk>

¹⁷ <http://www.gemeentegeschiedenis.nl>

¹⁸ <http://histopo.nl>

¹⁹ <http://pleiades.stoa.org>

²⁰ <http://commons.pelagios.org>

²¹ <http://www.dbpedia.org>

²² <http://viaf.org>

In below, we summarize how the HIPLA model and Hipla.fi system address the research challenges 1–4 set in Section 1, and in contrast with the related works above.

1. Contextualizing Historical Place Names. Gazetteers typically provide information based on one underlying register without external context. HIPLA advocates the idea of enriching historical place data by contextual data based on using Linked Data, as illustrated in the WarSampo application case based on Hipla.fi. It seems that this possibility is not much used in current gazetteers even if they were based on LD that would facilitate this. Hipla.fi data service supports URI dereferencing and traditional Linked Data browsing [4], providing also a kind of context for familiarizing oneself with the underlying data. This LD publishing idea of resolving external place URIs as data in different formats or as ready-to-use HTML pages for the end user to browse is used in LD-based gazetteers in different ways and to different degrees. Hipla.fi provides a complete LOD service for its own LD repositories.

2. Need for Historical Maps. In HIPLA, historical maps can be used for providing a historical context for places. There are several online systems for historical maps available. For example, OldMapsOnline²³ is a search engine for finding historical maps covering a given contemporary area. In contrast to Hipla.fi, this service comes without a historical gazetteer, and the maps are not rectified.

HIPLA includes a map service for aligning and viewing georectified historical maps, as in the New York Public Library’s Chronology of Place gazetteer²⁴. Major tools for rectifying maps include the open source tool Map Warper, employed in Hipla.fi, and the commercial Georeferencer²⁵. These systems focus on maps and are not data service gazetteers. HIPLA also publishes the metadata of the historical maps as Linked (Open) Data. The dynamic and transparent selection of the data sources makes it possible to understand the origins of the data.

3. Maintaining Evolving Historical Gazetteers. A novelty of the HIPLA model lies in the idea of crowdsourcing the creation of the ontologies by soliciting contributions from the catalogers of Cultural Heritage content, as a side effect of their daily work. This idea is different from systems like Pleiades or GeoNames that crowdsource volunteers’ work in gazetteer development. We envision that sustainable gazetteer maintenance should involve not only gazetteer developers but also their users.

4. Managing Distributed Historical Gazetteers. HIPLA is a brokering service that not only aggregates the data for humans but also for machines (legacy cataloging systems) using the SPARQL endpoint APIs of the participating data services. The service itself hosts a triple store of shared suggested new places and map metadata. The proposed brokering solution bears resemblance to idea of “normalized ontology repositories” [15] where distributed ontology services are normalized using shared SKOS-based APIs and are combined into a larger service. In HIPLA, SPARQL is used for normalization and the domain is historical gazetteers. This idea is also related to the VIAF model where authority files from different sources are mapped to each other using *owl:sameAs*, and are given unifying URIs in a new namespace. In our case, such

²³ <http://www.oldmapsonline.org>

²⁴ <http://nypl.gazetteer.us>

²⁵ <http://www.georeferencer.com>

mappings and URIs are not created or maintained. The choice of what URIs to use is left to the end user.

Acknowledgements Hanna Hyvönen rectified Hipla.fi maps and Eetu Mäkelä contributed in creating gazetteers. Our work was supported by the Finnish Cultural Foundation and the Wikidata Project of Wikimedia Finland.

References

1. Ashish, N., Sheth, A. (eds.): *Geospatial Semantics and Semantic Web: Foundations, Algorithms, and Applications*. Springer-Verlag (2011)
2. d'Aquin, M., Noy, N.F.: Where to publish and find ontologies? A survey of ontology libraries. *Web Semantics: Science, Services and Agents on the World Wide Web* 11, 96–111 (2012)
3. Elliott, T., Gillies, S.: Digital geography and classics. *Digital Humanities Quarterly* 3(1) (2009), <http://www.digitalhumanities.org/dhq/vol/3/1/000031.html>
4. Heath, T., Bizer, C.: *Linked Data: Evolving the Web into a Global Data Space* (1st edition). *Synthesis Lectures on the Semantic Web: Theory and Technology*, Morgan & Claypool (2011), <http://linkeddatabook.com/editions/1.0/>
5. Hill, L.: *Georeferencing: The geographic associations of information*. MIT Press (2009)
6. Hill, L., Frew, J., Zheng, Q.: Geographic names: The implementation of a gazetteer in a georeferenced digital library. *D-Lib* 5(1) (1999), <http://www.dlib.org/dlib/january99/hill/01hill.html>
7. Hyvönen, E., Tuominen, J., Alonen, M., Mäkelä, E.: Linked Data Finland: A 7-star model and platform for publishing and re-using linked datasets. In: *The Semantic Web: ESWC 2014 Satellite Events, Revised Selected Papers*, pp. 226–230. Springer-Verlag (2014)
8. Hyvönen, E., Tuominen, J., Ikkala, E., Mäkelä, E.: Ontology services based on crowdsourcing: Case national gazetteer of historical places. In: *Proc. of the ISWC 2015 Posters & Demonstrations Track. CEUR-WS Proceedings* (2015), <http://www.ceur-ws.org/Vol-1486>, vol 1486
9. Hyvönen, E., Tuominen, J., Kauppinen, T., Väättäin, J.: Representing and utilizing changing historical places as an ontology time series. In: Ashish and Sheth [1], pp. 1–25
10. Hyvönen, E., Heino, E., Leskinen, P., Ikkala, E., Koho, M., Tamper, M., Tuominen, J., Mäkelä, E.: WarSampo data service and semantic portal for publishing linked open data about the second world war history. In: *Proc. of ESWC 2016*. Springer-Verlag (2016)
11. Ikkala, E., Tuominen, J., Hyvönen, E.: Contextualizing historical places in a gazetteer by using historical maps and linked data. In: *Proc. of Digital Humanities 2016, short papers* (2016)
12. Southall, H., Mostern, R., Berman, M.L.: On historical gazetteers. *International Journal of Humanities and Arts Computing* 5(2), 127–145 (2011)
13. Tuominen, J., Frosterus, M., Viljanen, K., Hyvönen, E.: ONKI SKOS server for publishing and utilizing SKOS vocabularies and ontologies as services. In: *Proc. of the 6th European Semantic Web Conference (ESWC 2009)*, pp. 768–780. Springer-Verlag (2009)
14. Viljanen, K., Tuominen, J., Käsälä, T., Hyvönen, E.: Distributed semantic content creation and publication for cultural heritage legacy systems. In: *Proc. of the 2008 IEEE International Conference on Distributed Human-Machine Systems*, pp. 335–340. IEEE Press (2008)
15. Viljanen, K., Tuominen, J., Mäkelä, E., Hyvönen, E.: Normalized access to ontology repositories. In: *Proc. of the Sixth International Conference on Semantic Computing (IEEE ICSC 2012)*, pp. 109–116. IEEE Press (2012)