FindSampo: A Linked Data Based Portal and Data Service for Analyzing and Disseminating Archaeological Object Finds

Heikki Rantala[1], Esko Ikkala[1], Ville Rohiola[3], Mikko Koho[1,2], Jouni Tuominen[1,2], Eljas Oksanen[2], Anna Wessman[4], and Eero Hyvönen[1,2]

[1] Semantic Computing Research Group (SeCo), Aalto University, Finland and
http://seco.cs.aalto.fi
firstname.lastname@aalto.fi
[2] HELDIG – Helsinki Centre for Digital Humanities, University of Helsinki, Finland
http://heldig.fi
firstname.lastname@helsinki.fi
[3] Finnish Heritage Agency
firstname.lastname@museovirasto.fi
[4] University Museum of Bergen
firstname.lastname@uib.no

Abstract. This paper presents the FindSampo system for analyzing and disseminating archaeological object finds made by the public. The system is based on Linked Open Data (LOD), and consists of a web portal and an open data service. The underlying knowledge graph contains data of some 3000 archaeological object finds catalogued in the archaeological collection of the Finnish Heritage Agency (FHA) from 2015 to 2020. The portal and LOD service have been open to public use since May 2021.

1 Introduction

1.1 Web Services for Citizens and Researchers

The popularity of recreational metal detecting has grown rapidly in many countries such as in Finland during the last decade, creating a large amount of new archaeological data. This paper demonstrates how archaeological object finds made by the public can be analyzed using the Linked Open Data (LOD) based FindSampo service [11, 15]. FindSampo research prototype has been created by the SuALT project[5] aiming to study and improve the reporting process and analysis of archaeological finds based on collaboration of the public, academic researchers, archaeologists, and the FHA [4, 23, 17].

A demonstrator based on data of some 3000 archaeological object finds catalogued in the archaeological collection of the Finnish Heritage Agency (FHA) from 2015 to 2020 has been open to public use since May 2021, and has had over 3000 users during it's first six months. FindSampo demonstrator consists

[5] SuALT project: https://blogs.helsinki.fi/sualt-project

of a data service[6] and a semantic portal[7] with search functions and analytical tools. Figure 1 shows the front page of the FindSampo portal with various perspectives to the data, and quick links to selected featured finds.

FindSampo responds to a need for digital solutions to improve the management, accessibility and democratisation in cultural heritage management that stem from the recent popularity of recreational metal-detecting. In Finland, metal detecting is permitted but the Finnish Antiquities Act (295/1963) stipulates acts of law that must be followed also when metal detecting. There are also gerenal guidelines provided for recreational metal detectorists to prevent illegal acts and to protect cultural heritage. The Antiquities Act prohibits strictly metal detecting and especially digging at the ancient monuments and other archaeological sites. Certain areas are also protected by the Nature Conservaton Act. The Antiquities Act also requires that archaeological objects, including metal detected finds are expected to be at least 100 years old and do not have any known owner must be reported immediately to the FHA. The reporting of finds is guided to be done easily through FHA's electronic reporting service. In Finland, the FHA has the right to redeem archaeological finds to the national collections.[8] In the management process of the finds, the find information will also be entered into an electronic database that will feed the FindSampo. Metal-detecting is therefore a form of crowd-sourcing information about the past. For the more serious (or avocational) metal-detectorists this activity is citizen science, where the citizen participates in the creation and discovery of new archaeological knowledge [24].

Metal-detecting in Finland has increased significantly in popularity in the last decade. The vastly increased amount of information generated challenges the heritage management. The larger context that this topic consequently links to is the pan-European need to develop an internationally operable and harmonised data infrastructure for using cultural heritage data from different countries in research.

In order to respond to the challenges in contemporary cultural heritage management, the FindSampo data service and portal supports three overlapping stakeholder groups: 1) the public in analysing their finds and learning about archaeology, 2) cultural heritage professionals in analysing, managing, and publishing collection data, and 3) researchers in knowledge discovery using metal-detected citizen science data. In keeping with the ethos of open science and democratising access to cultural heritage the service has been designed to transfer knowledge from professionals to citizen scientists, and to provide a powerful set of digital tools for new knowledge discovery and creation among its users.

The archaeological finds included in the service have been recovered by the public mainly by metal-detecting and reported to the FHA for recording. The FindSampo data constitutes an unprecedented reservoir of citizen science-

[6] https://www.ldf.fi/dataset/findsampo
[7] https://loytosampo.fi/en
[8] https://www.museovirasto.fi/uploads/Arkisto-ja-kokoelmapalvelut/Julkaisut/muinaisjaannokset-ja-metallinetsin-2017.pdf

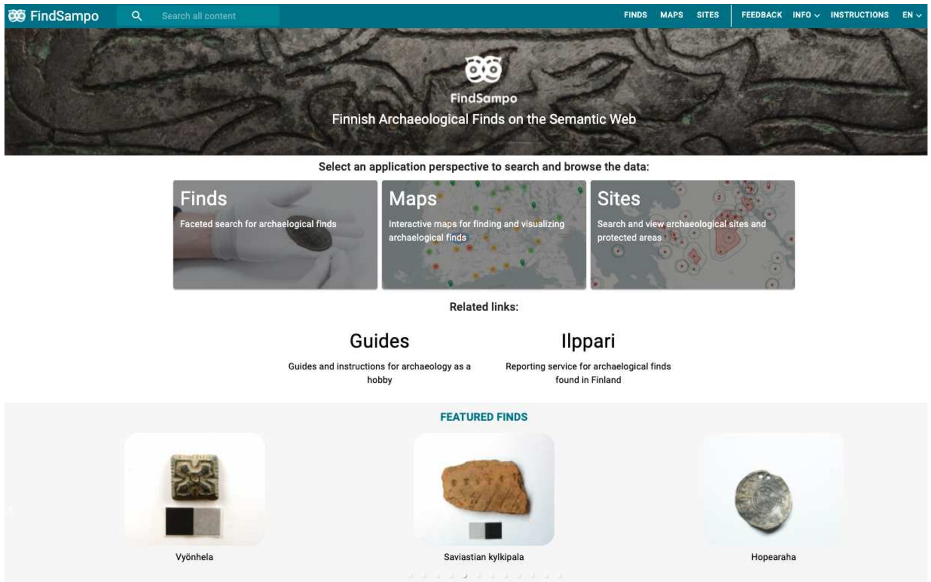

Fig. 1. Front page of the FindSampo portal.

generated archaeological heritage in Finland, equally accessible to researchers and to the broader public interested in heritage. The new archaeological object finds material it contains has proven to hold the potential for substantially adding to our understanding of the Finnish prehistorical and historical periods. Our goal is to allow the end users to improve themselves and also learn more about archaeology. In this way, archaeological data becomes more quickly and comprehensively available and accessible for research purposes and Digital Humanities [3].

This paper presents an overview the service and the technical design principles and implementation of the FindSampo Portal and the underlying data service. FindSampo Portal is yet another member in the "Sampo" series[9] of Linked Open Data services and semantic portals [9], based on a national Semantic Web infrastructure [8].

1.2 Related Work

Our work was motivated by the growing popularity of metal detecting in recent years. As a result, many countries are developing web services to collect, analyse, and study archaeological data.

[9] For a list of Sampo portals, see https://seco.cs.aalto.fi/applications/sampo/.

1. The largest of them, Portable Antiquities Scheme (PAS)[10], records[11] archaeological discoveries found by members of the public in England and Wales since 1997 [1].
2. Digital Metal Finds (DIME)[12] is an online platform for reporting metal detecting finds in Denmark [22].
3. Portable Antiquities of the Netherlands (PAN)[13] is an online portal in use in the Netherlands [20].
4. Metal-Detected Artefacts (MEDEA)[14] is an online portal developed in Flanders for metal detectors [2, 22]; 5) ILPPARI[15] is a service of the Finnish Heritage Agency (FHA) for reporting archaeological object finds found by the public in Finland. The service also includes tools for public to report archaeological sites and possible damages concurred to them. [23].

FindSampo is an application of the "Sampo model" [10], a collection principles that have evolved gradually when creating a series of semantic portals[16]. The principles behind the Sampo model in use in FindSampo have been explored and developed before in different contexts. For example, the notion of collaborative content creation by data linking is a fundamental idea behind the Linked Open Data Cloud movement[17] and has been developed also in various other settings, e.g., in ResearchSpace[18]. The idea of providing multiple analyses and visualizations to a set of filtered search results has been used in other portals, such as the ePistolarium[19] [16] for epistolary data, and using multiple perspectives have been studied as an approach in decision making [13]. Faceted search [18, 19], also known as "view-based search" and "dynamic ontologies", is a well-known paradigm for explorative search and browsing [14] in computer science and information retrieval, based on S. R. Ranaganathan's original ideas of faceted classification in Libary Science in the 1930's. The two step filter-analyse usage model is used in prosopographical research [21] (without the faceted search component). The novelty of the Sampo model lies in consolidating several ideas and in operationalizing them for developing applications in Digital Humanities; something that the field of the Semantic Web seems to be missing as argued in [5].

1.3 Applying the Sampo Model on a Framework Level

The Sampo model principles can be used directly for creating semantic portals. However, its is also possible to apply them first to create an application do-

[10] PAS: https://finds.org.uk/database
[11] 1.4 million finds have been reported by more than 14,000 citizens by now.
[12] DIME: https://www.metaldetektorfund.dk
[13] PAN: https://portable-antiquities.nl
[14] MEDEA: https://vondsten.be
[15] ILPPARI: https://www.kyppi.fi/ilppari
[16] This series is explained with references in https://seco.cs.aalto.fi/applications/sampo/.
[17] https://lod-cloud.net
[18] https://www.researchspace.org
[19] http://ckcc.huygens.knaw.nl

main specific framework and reuse it for developing different related application instances, which is arguably cost-efficient. Fig. 2 illustrates the idea with LetterSampo [6] and FindSampo frameworks as examples. The highest conceptual layer includes the Sampo model with its principles based on domain agnostic, logical SW standards of the W3C and Linked Data publishing principles. On the next, domain specific level, model level solutions and principles are applied to create a domain specific framework by using a domain specific data model that can be populated using domain specific vocabularies and ontologies (e.g., archaeological object types, archives involved, historical places, etc.). This layer includes also a domain specific template designed using the Sampo-UI framework [12] that can be copied and used as a starting point for creating application instances. The template tells, e.g., what thematic application perspectives, data-analysis tools, and ready-to-use UI components are available in this application domain. Finally, applications can be created by adding in specific datasets into the framework, by creating a Sampo-UI implementation of the portal interface, and by publishing the data in a Linked Data service with a SPARQL endpoint. In the figure, LetterSampo has been used for three such applications corresponding to the epistolary datasets CKCC, EMLO, and correspSearch. In the case of FindSampo, archaeological find collections from the Finnish National Museum are used in one intance and another one based of the Portable Antiquities Schema of the British Museum is being developed using the same framework.

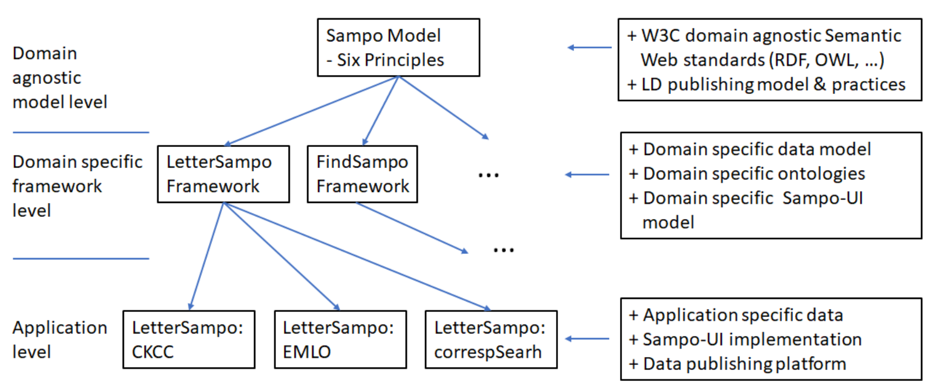

Fig. 2. Three conceptual layers for creating Sampo portals: Sampo Model, Sampo frameworks, and applications [6]. The idea is to re-use generic solutions of the model layer in domain specific frameworks and then frameworks for application instances in different domains.

2 FindSampo Data Model and Data Service

2.1 Data Model

For the heritage agencies in Finland, and presumably around the world, a central problem are the limited available resources for information technology. We have therefore tried to use as simple model for the data as possible, instead of for example the CICOD Conceptual Reference Model (CRM)[20]. CIDOC CRM appeared far too complex for the relatively simple data relating to the object finds.

We created a FindSampo Core ontology for representing the most relevant data relating to the object finds. The FindSampo datamodel is mainly table like. There are Find entities representing the object finds, and almost all the data is attached to those with simple properties. The FindSampo core properties include properties for object type, material, dating, and so on. We would expect any data relating to citizen science object finds would generally include these properties. In addition to the core properties we use specific properties to represent the data as it is in it's original source. These properties would be different for all different sources, and represent the data in the format used in that source. There can also be various properties for types of data that is not included as part of core properties. While the core properties aim to use ontologized object values, and standard data types, these source specific properties are only literal can can use various different data types.

Below is presented a simplified example, with selected properties, of a RDF representation of a single Find in Turtle format. Most of the properties here are either core properties, represented with prefix findsampo-core or properties specific to the FHA finds database, that are represented with the prefix "ltk-s". For example, in the Turtle notation below the property "ltk-s:length" denotes the original value for the object length in the FHA database as it is written there. The property "findsampo-core:length" on the other hand expresses the object length in standard decimal format. We also use SKOS prefLabel property for the main human readable label of the find, and we use Dublin Core source property to represent the source of data for the Find. Most properties attach the data directly to the Find, but with time spans and coordinate points we use a more complex representation where they are separate entities that use to some extended standard CIDOC CRM or the W3C basic geographic vocabulary[21]. This is to make is to make it easier to integrate to the various existing tools.

```
@prefix crm: <http://erlangen-crm.org/current/> .
@prefix dct: <http://purl.org/dc/terms/> .
@prefix ltk-s: <http://ldf.fi/schema/findsampo/extended/ltk/> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix findsampo-core: <http://ldf.fi/schema/findsampo/core/> .
@prefix finds: <http://ldf.fi/findsampo/finds/> .
```

[20] https://www.cidoc-crm.org/
[21] https://www.w3.org/2003/01/geo/

```
finds:km_39824-45 a findsampo-core:Find ;
    findsampo-core:find_site_coordinates
      <http://ldf.fi/findsampo/find_sites/find_site_of_39824-45> ;
    findsampo-core:has_creation_time_span
      [ crm:P82a_begin_of_the_begin "-0500-01-01"^^xsd:date ;
      crm:P82b_end_of_the_end "1300-12-31"^^xsd:date ] ;
    findsampo-core:identifier "KM39824:45" ;
    findsampo-core:length 56.0 ;
    findsampo-core:material
      <http://ldf.fi/findsampo/materials/p10> ;
    findsampo-core:object_type
      <http://ldf.fi/findsampo/object_types/hevosenkenkaesoljet> ;
    findsampo-core:period
      <http://ldf.fi/findsampo/periods/p17> ;
    findsampo-core:weight 35.0 ;
    findsampo-core:width 10.0 ;
    ltk-s:amount "1" ;
    ltk-s:find_name "Hevosenkenkäsolki" ;
    ltk-s:find_number "39824:45" ;
    ltk-s:length "56" ;
    dct:source "Museoviraston löytötietokanta" ;
    skos:prefLabel "Hevosenkenkäsolki KM39824:45" .
```

In the end, creating a simple model for the relevant properties of object finds is relatively easy. Internationally the central properties of the data seem to be mostly similar, and the data from other countries could be represent with this model as well. We have already created an initial conversion of PAS data to FindSampo model to run tests with it using our system. What is a more difficult question is the harmonization of various ontologies used in the data.

2.2 Ontologies

Representing the properties of object finds requires specific ontologies. These include especially ontologies for object type, materials, and periods. We have used the Finnish Ontology for Museum Domain and Applied Arts (MAO/TAO)[22] as the basis of the ontologies. MAO/TAO ontology includes most of the relevant vocabulary and a concept hierarchy. However the hierarchy can be difficult to use in practice, and it can be difficult to, for example, find the relevant vocabulary for object types. We have developed new hierarchies for easier use. The MAO/TAO ontology is also only a relatively simple SKOS[23] vocabulary, and is lacking semantic information, such as machine readable dates for periods. We

[22] https://finto.fi/maotao/en/

[23] https://www.w3.org/2004/02/skos/

have added such semantic information and also created mappings to international vocabularies.

We have used two different kinds of ontologies to represent the data: annotation ontologies and facet ontologies. Annotation ontologies are used to represent the concepts in the data in shared and machine understandable manner, while the facet ontologies are used to offer an easy to use hierarchy of concepts to the users. We have used the Finnish MAO ontology as the basis of our annotatio ontologies, but instead of using MAO identifiers directly, we have created new identifiers for the concepts, that then have an exact match concept in MAO ontology. In some cases we have created new concepts that do not currenty exist in MAO, but that were deemed necessary during the SuALT project and are planned to be added to MAO later.

While the MAO ontology has a hierarchy for the concepts, the concepts are scattered around and can be difficult to use in practice. We have created facet ontologies for relevant concepts, especially the object types, to make searching and analyzing the finds easier. MAO ontology is created using strict ontological principles where an instance of a narrower concept can always be deduced to be also an instance of a broader concept. This means that for example the term ”sword's hilt” can't have a broader term ”sword” because sword's hilt is not actually a sword, unlike for example a sword is a weapon. In many cases it would however be preferable to have 'sword's hilt” in hierarchy under ”sword”. This will be more intuitive for a casual user of the web portal, and this can also be useful for a researcher. For example when a researcher would like to visualize find sites of iron age swords on a map, it isn't usually relevant if the find is a sword or only a part of a sword, and it is more convenient to simply select swords than having to know to select the sword and parts of swords.

It would have been possible to create the facet ontologies with some ontology editor. However, to make the creation easier, we opted to use a method where the hierarchies were created using a spread sheet and hierarchy was indicated using different column, so that the concepts on the first column is on the top level if the hierarchy, and a concept on the second column is a narrower concept of the first concept above it in the spreadsheet on the first column, and so on. We then had a purpose built Python script to convert these spreadsheets to RDF format. Using such method meant that an archaeology expert creating the facet ontology did not have to learn to use the often quite complex ontology editors. On the other hand some issues became apparent only when the ontologies were actually put to use. An ontology editor would better show how the hierarchy actually operates and would also help to avoid some spelling errors.

We created mappings for the Finnish MAO terms to international ontologies, especially the Getty Art & Architecture Thesaurus[24] (AAT), to allow easy comparison of the Finnish find data to similar international data. A mapping to ATT allows also linking to other international vocabularies through AAT. For example we have used a mapping created by the Ariadne[25] project between the

[24] https://www.getty.edu/research/tools/vocabularies/aat/
[25] http://legacy.ariadne-infrastructure.eu/

AAT and the Forum on Information Standards in Heritage (FISH) Archaeological Objects Thesaurus[26] to create mapping between the Finnish ontology and the FISH ontology that is used for example by the The Portable Antiquities Scheme (PAS) of the British Museum.

While ontologizing the terms used for periods and materials in the FHA data, the terms for object types required more work. The current find database of FHA allows submitting data freely and no strict vocabulary has been used. We mapped the object types of finds to MAO ontology using "object names" of each object. This was the most detailed description of the type of the objects available in structured format in the find database. All the object names of metal detecting finds in the database were mapped to MAO terms. The object names were on the level of "sword" but not including a more detailed type such as "Petersen Type E sword" this kind of exact type was sometimes included in a separate data field or in the free text description, but determining such things automatically would have been difficult. The MAO ontology includes a term for "Petersen Type E swords" but the automatic mapping means that such objects would currently only get "sword" as their object type. The most specific term available should ideally be used, but these will need to be added manually at a later date by archaeology experts where possible. The exact level of detail how a specific find can in practice be classified by experts may vary.

2.3 Data Conversion

Source data of FindSampo is received in CSV format and is converted to RDF. The conversion pipeline consist of two main parts: the data conversion and the ontology conversion. The both processes use Python scripts mainly based on RDFLib[27] library, that convert CSV files to RDF. Fig. 3 shows the basic steps in the conversion process.

First part of the pipeline is the ontology creation process, where the ontologies defined in CSV are converted to RDF format. The pipeline then runs an initial process that creates a simple RDF file with only literal values. Enriching process is then run which cleans up data and creates ontologized values for data based on the ontology definitions. After the data is updated, a triple store is automatically built with the updated data.

The data and ontology conversions are done with similar Python scripts for convenience, but the processes are not depended on each other and they could be done separately and in different ways. Ideally the existing ontology infrastructure would be so strong that we could use entirely ready made ontologies.

We do not use SPARQL update protocol, but instead run the whole conversion pipeline again when the source data is updated and the triple store is automatically build again with new data. The LOD service is run on the Linked Data Finland platform[28] [7], which is powered by a combination of the Fuseki

[26] http://www.heritage-standards.org.uk/fish-vocabularies/
[27] https://rdflib.readthedocs.io/en/stable/
[28] https://ldf.fi

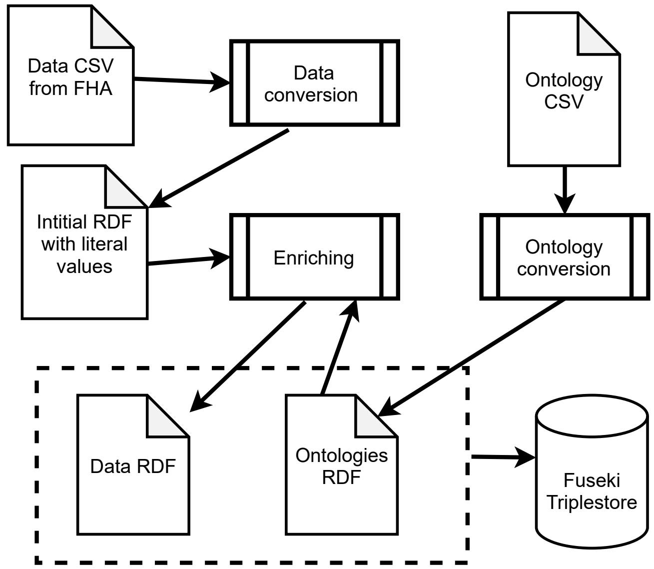

Fig. 3. Conversion pipeline

SPARQL server[29] and a Varnish Cache web application accelerator[30] for routing URIs, content negotiation, and caching.

3 FindSampo Semantic Portal

The FindSampo Data Service includes currently over 3000 archaeological finds made by the public. The FindSampo Portal queries this data service with SPARQL, and offers search, exploration, and analysis tools for DH researchers and hobbyists. The finds can be filtered using faceted search [18] with hierarchical facets based on ontologies, and then visualized using maps with external layers from the GIS services[31] of the FHA, various types of charts, and a timeline. On the front page, see Figure 1, the user is presented with tree different perspectives: "Finds", "Maps", and "Sites".

The Finds perspective allows for searching and analyzing the archaeological object finds in the knowledge graph using facets and various visualizations. Maps perspective here is just a quick link for user for map visualizations o f this perspective. Faceted search can be used to get the information of some specific find, and it can also be used to analyze and compare groups of finds. As default the individual finds are presented as a table as the default option on wider screens, or as a more mobile friendly list with mobile devices. The mobile friendly list

[29] https://jena.apache.org/documentation/fuseki2/
[30] https://varnish-cache.org
[31] https://kartta.museoverkko.fi/?lang=en

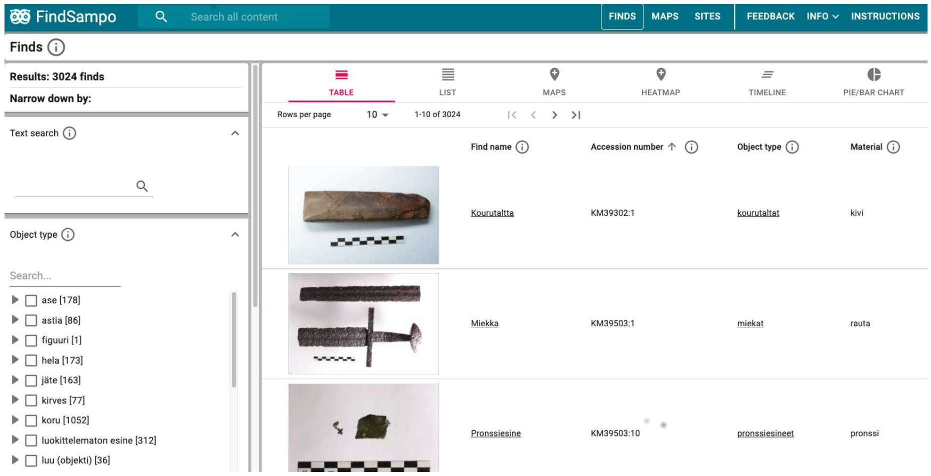

Fig. 4. The main search view of FindSampo portal showing finds as a paginated table on the right, and search facets on the left.

option was created after the initial publication of the portal based on feedback from metal detectorists. Figure 4 shows one opened facet and results with a pictures of individual finds when available. The various charts and timelines can be selected from tabs to visualize the relative distributions of the selected groups of finds. Currently the user can select visualizations from clustered map, heatmap, timeline, pie or bar charts, and line charts. In addition there is an option to download the data in CSV format.

The clustered map shows interactive markers on a map based on the find coordinates of each find. The clustering is made for performance reasons. The finds can be visualized using different base maps and map layers (selected in the box on the top right) including, e.g., street maps, satellite images, and a lidar-based elevation model.

Heatmap is a more research oriented tool that shows the data about the finds as a spatial heatmap. Figure 6 shows an example of a simple visualization for data-analysis, that can be made easily. The user has selected prehistory period from the period facet and the heatmap tab to view the results. It is easy to see that the red area, that signify a lot of nearby finds, are concentrated in Häme and close to the city of Turku, and large areas of Finland have only a small number of finds. A researcher will have to determine if this tells something about the prehistory of Finland, or if this is related more to the popularity of metal-detecting hobby in certain areas.

The timeline tab can be used to visualize temporal spread of groups of finds in certain areas. Timeline component groups the finds by province in which they were found (y-axis), and by period (x-axis). The start and end years for the periods are retrieved from the period ontology developed with domain experts, instead of directly from the finds. Pie chart tab can be used to visualize distri-

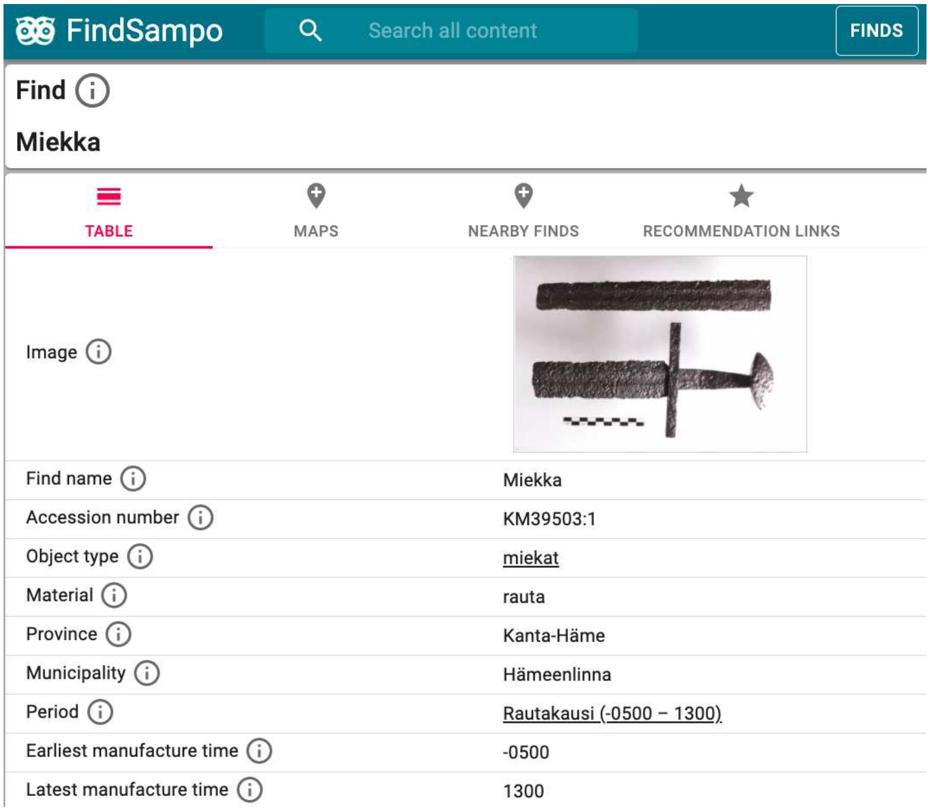

Fig. 5. An entity landing page of a single find.

butions as pie or bar charts. These can be used to easily visualize, for example, the relative number of coins in finds from the medieval period.

Each individual object find has its own "home page" that contains detailed information about the find. Figure 5 shows an example of an entity landing page of a single find. This entity page of the find includes the detailed information of the find, a map showing the find coordinates, and recommended links to similar finds in Finland and abroad. The object types and periods have their own pages in the same way. The collect information such as the time span of a certain period and links to the related finds.

We have created links to PAS data as an example of connecting international data. This feature shows the possibilities and challenges that a linked data approach can have. The links to PAS as created through mapping FindSampo object types to AAT vocabulary, that is then mapped the FISH vocabulary used by PAS. This means that there is one extra step that can cause various issues for the linking. In practice this can be seen in that in many cases a link is missing, or it can be less than optimal. For example an entity page of a sword find, as in figure 5, has a link to a certain object in PAS database that is determined to be similar, based on it's type "sword". Similarly entity page of object type of swords has a link to PAS database search for swords. In practice this can take take user to a page of a sword pommel, as those are expressed in PAS data o be of type "sword". The accuracy of this kind of mapping is limited to the least accurate conceptualization.

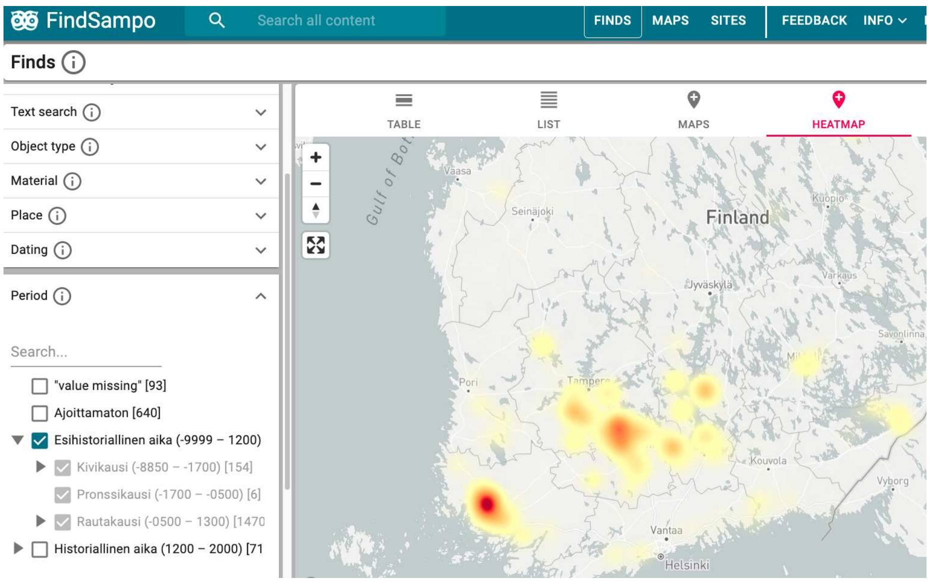

Fig. 6. An example of of using FindSampo portal for data analysis: showing prehistoric finds as a heatmap.

The Sites perspective can be used to show finds made by the public and the registered archaeological sites of FHA. This data is received directly from FHA API. As an example, Fig. 7 shows finds (green markers, one of which is opened) and protected archaeological sites (red areas) along the Aura River in Turku, the former capital of Finland. A buffer zone of 200 meters where metal detecting is not recommended is automatically calculated and shown around the sites with a dashed line. The maps can be used by researchers for analysis, and by hobbyists to get information on promising places to practice metal detecting as well as on protected sites where detecting should be avoided. This kind of mobile friendly map is particularly useful for metal-detectorists.

The user interface of the portal is implemented with the Sampo-UI framework [12], and the source code is available on GitHub[32] with an open license. The performance of the portal is

[32] https://github.com/SemanticComputing/findsampo-web-app

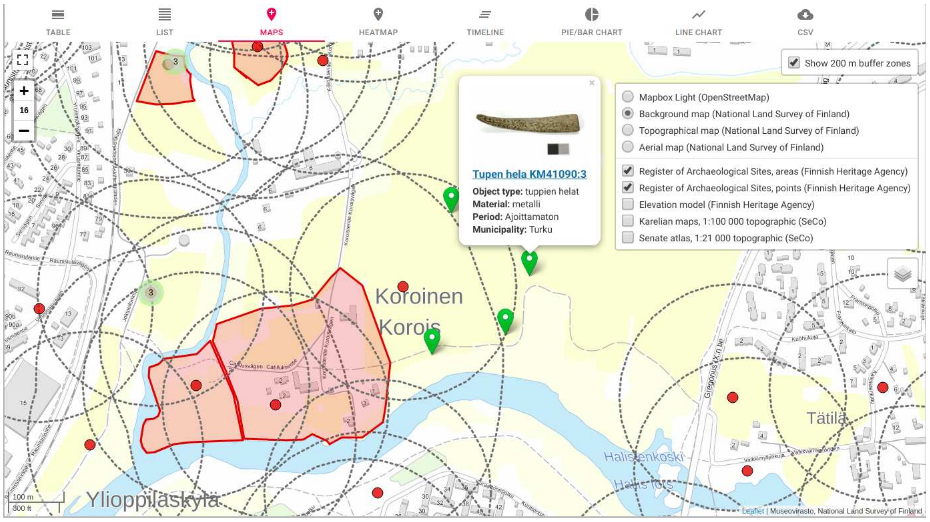

Fig. 7. Archaeological finds and protected sites along the Aura River in the City of Turku as shown in the FindSampo portal.

4 Discussion

4.1 Contributions

The apps built into the FindSampo offer a powerful set of tools for examining and analysing archaeological finds, and creating new knowledge and understanding of the past. As an archaeological cultural heritage service FindSampo has been designed to organise, present and make widely available a complex form of crowd-sourced and heterogenous data.

Metal-detected public archaeology is an inherently international field. Find data cannot be viewed as restrictively national cultural heritage, and from a research and knowledge discovery perspective the various public finds archaeological databases are natural partners to each other. LOD offers a natural way of harmonizing international data in a way that makes interoperability possible. Mapping created to international vocabularies from FindSampo concepts make possible to create research of metal-detected finds that transcendents data from single countries. The data model of FindSampo also offer a way to represent such find data in simple and interoperable way.

4.2 Future work

In future we aim to continue update FindSampo with new finds made my metal-detectorists in Finland. We also are starting a continuation project that seeks to add a a new perspective to FindSampo that is concentrated to coins. Coins are a special case of object finds as they are very numerous, and have many coin specific properties, such as mint or ruler, that other finds generally do not have.

FindSampo is part of a larger pan-European movement in digital cultural heritage services. Major undertakings such as the EU-funded ARIADNEplus project[33] are presently developing data alignment methodology for combining diverse national archaeological databases. Research for transnational data services based on the FindSampo framework is currently being taken forward by a new pilot project funded by the Helsinki Institute for Social Sciences and Humanities at the University of Helsinki, which seeks to integrate the PAS dataset within the FindSampo framework as a test case of its international use-potential.

Acknowledgements Our work was funded mostly by the Academy of Finland. The authors wish to acknowledge CSC – IT Center for Science, Finland, for providing computational resources.

References

1. Daubney, A., Nicholas, L.E.: Detecting Heritage Crime(s): What We Know about Illicit Metal Detecting in England and Wales. International Journal of Cultural Property **26**, 139–165 (May 2019). https://doi.org/10.1017/S0940739119000158
2. Deckers, P., Bleumers, L., Ruelens, S., Lemmens, B., Vanderperren, N., Marchal, C., Pierson, J., Tys, D.: MEDEA: Crowd-Sourcing the Recording of Metal-Detected Artefacts in Flanders (Belgium). Open Archaeology **2**(1), 264–277 (June 2016). https://doi.org/10.1515/opar-2016-0019
3. Gardiner, E., Musto, R.G.: The Digital Humanities: A Primer for Students and Scholars. Cambridge University Press, New York, NY, USA (2015)
4. Hassanzadeh, P.: FindSampo: A Citizen Science Platform for Archaeological Finds on the Semantic Web. Master's thesis, Aalto University, School of Science, Finland (December 2019), http://urn.fi/URN:NBN:fi:aalto-201912226669
5. Hitzler, P.: A review of the semantic web field. Commun. ACM **64**(2), 76–83 (Jan 2021). https://doi.org/10.1145/3397512
6. Hyvönen, E., Leskinen, P., Tuominen, J.: Lettersampo – historical letters on the semantic web: A framework and its application to publishing and using epistolary data of the Republic of Letters (2021), https://seco.cs.aalto.fi/publications/2020/hyvonen-et-al-lettersampo-2020.pdf, submitted for peer review
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: European Semantic Web Conference. vol. 8798, pp. 226–230 (May 2014). https://doi.org/10.1007/978-3-319-11955-7_24
8. Hyvönen, E.: Linked Open Data Infrastructure for Digital Humanities in Finland. In: Digital Humanities in Nordic Countries, 5th Conference (DHN 2020), Proceedings, accepted. CEUR WS Proceedings (2020), https://seco.cs.aalto.fi/publications/2020/hyvonen-lodi4dh-dhn-2020.pdf
9. Hyvönen, E.: "Sampo" model and semantic portals for digital humanities on the Semantic Web. In: Digital Humanities in Nordic Countries, 5th Conference (DHN 2020), Proceedings, accepted. CEUR WS Proceedings (2020), https://seco.cs.aalto.fi/publications/2020/hyvonen-sampos-dhn-2020.pdf

[33] https://ariadne-infrastructure.eu/

10. Hyvönen, E.: Digital humanities on the semantic web: Sampo model and portal series (April 2021), http://semantic-web-journal.org/content/digital-humanities-semantic-web-sampo-model-and-portal-series, submitted
11. Hyvönen, E., Rantala, H., Ikkala, E., Koho, M., Tuominen, J., Anafi, B., Thomas, S., Wessman, A., Oksanen, E., Rohiola, V., Kuitunen, J., Ryyppö, M.: Citizen science archaeological finds on the semantic web: The findsampo framework. Antiquity, A Review of World Archaeology **95**(382), e24 (August 2021). https://doi.org/10.15184/aqy.2021.87
12. Ikkala, E., Hyvönen, E., Rantala, H., Koho, M.: Sampo-UI: A full stack JavaScript framework for developing semantic portal user interfaces. Semantic Web – Interoperability, Usability, Applicability **13**(1), 69–84 (2022). https://doi.org/10.3233/SW-210428
13. Linstone, H.A.: Multiple perspectives: Concept, applications, and user guidelines. Systems practice **2**(3), 307–331 (1989). https://doi.org/10.1007/BF01059977
14. Marchionini, G.: Exploratory search: From finding to understanding. Commun. of ACM **49**(4), 41–46 (April 2006). https://doi.org/10.1145/1121949.1121979
15. Rantala, H., Ikkala, E., Koho, M., Tuominen, J., Rohiola, V., Hyvönen, E.: Using findsampo linked open data service and portal for spatio-temporal data analysis of archaeological finds in digital humanities. In: ISWC-Posters-Demos-Industry 2021 International Semantic Web Conference (ISWC) 2021: Posters, Demos, and Industry Tracks. CEUR Workshop Proceedings (Oct 2021), http://ceur-ws.org/Vol-2980/paper330.pdf
16. Ravenek, W., van den Heuvel, C., Gerritsen, G.: The ePistolarium: Origins and techniques. In: van Hessen, A., Odijk, J. (eds.) CLARIN in the Low Countries. pp. 317–323. Ubiquity Press (2017). https://doi.org/10.5334/bbi
17. Thomas, S., Wessman, A., Tuominen, J., Koho, M., Ikkala, E., Hyvönen, E., Rohiola, V., Salmela, U.: SuALT: Collaborative Research Infrastructure for Archaeological Finds and Public Engagement through Linked Open Data. In: Digital Humanities in the Nordic Countries, 3rd Conference (DHN 2018) (2018)
18. Tunkelang, D.: Faceted search. Synthesis Lectures on Information Concepts, Retrieval, and Services **1**(1), 1–80 (2009)
19. Tzitzikas, Y., Manolis, N., Papadakos, P.: Faceted exploration of RDF/S datasets: a survey. Journal of Intelligent Information Systems **48**(2), 329–364 (2017)
20. Veen, V.: The Netherlands during the Napoleonic Era (1794–1815). Using detector finds to shed light on an under-researched period. In: Methods in Conflict Archaeology, 10th Fields of Conflict Conference. vol. 1, pp. 19–30. Mashantucket Pequot Museum & Research Center (September 2018)
21. Verboven, K., Carlier, M., Dumolyn, J.: A short manual to the art of prosopography. In: Prosopography approaches and applications. A handbook, pp. 35–70. Unit for Prosopographical Research (Linacre College) (2007)
22. Wessman, A., Thomas, S., Rohiola, V., Koho, M., Ikkala, E., Tuominen, J., Hyvönen, E., Kuitunen, J., Parviainen, H., Niukkanen, M.: Citizen Science in Archaeology: Developing a Collaborative Web Service for Archaeological Finds in Finland, pp. 337–352. Springer (June 2019). https://doi.org/10.1007/978-3-030-14327-5_23
23. Wessman, A., Thomas, S., Rohiola, V., Kuitunen, J., Ikkala, E., Tuominen, J., Koho, M., Hyvönen, E.: A Citizen Science Approach to Archaeology: Finnish Archaeological Finds Recording Linked Open Database (SuALT). In: Digital Humanities in the Nordic Countries 2019. pp. 469–478. CEUR Workshop Proceedings (May 2019)

24. Wessman, A.P.F., Thomas, S.E., Rohiola, V., et al.: Digital archaeology and citizen science:: Introducing the goals of findsampo and the sualt project. SKAS (2019)