Publishing Numismatic Public Finds on the Semantic Web for Digital Humanities Research – CoinSampo Linked Open Data Service and Semantic Portal

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Abstract
This paper presents the new web demonstrator and Linked Open Data (LOD) service CoinSampo. The data service is based on over 18 000 numismatic citizen science finds that were reported to the National Museum of Finland between 2013 and 2023, and which are enriched using external data sources by data linking. The data has been converted to LOD using light-weight facet ontologies. The CoinSampo web application offers users faceted semantic search and various integrated data-analytic visualization options. The application is aimed at a broad range of user audiences, including scientific researchers, heritage professionals, citizen scientists, amateur archaeologists, educators, and anyone interested in learning about the past.

Keywords
Linked Open Data, Numismatics, Archaeology, Digital Humanities,

1. Introduction

The number of metal-detected archaeological objects that have been recovered and reported by members of the public in Finland has considerably increased over the last ten years. Whereas the Finnish Heritage Agency (FHA) redeemed between 2000 and 2009 a total of 439 public finds into the national collections, today that number is nearing 2000 per annum [1, 2, 3]. Among these objects, coin finds have several characteristics that set them apart. Coin finds are usually one of the most, if not the most, common objects reported by the public (e.g., in the UK [4, 5]). Coins can be identified more precisely than many other common finds, producing higher quality record data and making them specially suitable for being described semantically as well as for Digital Humanities (DH) analysis. For example, authorities (rulers or institutions in whose name coins were issued) and mints (places where coins were struck) lend themselves naturally to being described by controlled vocabularies and ontologies. Historical coins moved internationally, making harmonizing and comparing international data especially relevant.

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The rapid increase in metal-detected finds in Finland parallels what is happening in several other European countries where metal-detecting is legal (albeit always with restrictions). While this new material has considerable advanced archaeological knowledge of the past, as well as arguably democratized and increased appreciation towards cultural heritage in general, it has also burdened traditional heritage management workflows and created significant new demands to open the data to researchers and the public – including the detectorists and citizen scientists who have recovered the finds in the first place [6, 7, 8].

As a solution to these challenges, this paper presents the demonstrator web application and LOD service CoinSampo, a new member in the Sampo series of systems [9]. CoinSampo was created using open data about numismatic public finds reported in Finland between 2013 and 2023. The CoinSampo web application[1] and data service[2] were opened to public on 28th February 2024. The knowledge graph (KG) includes some 620 000 triples and contains data about over 18 000 individual numismatic objects in RDF[3] format. The KG can be queried using SPARQL[4] query language from an open read-only endpoint[5]. The data is served through the Linked Data Finland[6] service, which, for example, takes care of resolving URIs.

CoinSampo was created as part of the *DigiNUMA – Digital Solutions for European Numismatic Heritage*[7] [1, 10, 11] project in response to new needs in Finnish and international Cultural Heritage (CH) data management, research, and dissemination using LOD. The data service and web application builds upon the FindSampo[8] [12] system, which has opened data of some 3000 archaeological public finds of all types that have been catalogued, acquired and redeemed into the national collections of the FHA. Since only prehistoric and medieval (before AD *c.* 1560) finds are consistently redeemed and recorded by the FHA, however, if this was the only source of public finds data a huge amount of later archaeological finds material would never be available. Unlike FindSampo, therefore, CoinSampo opens key data extracted from coin finds reports sent in by the public to the FHA, even if the numismatic objects themselves are never seen by heritage professionals or catalogued in a collections management system.

CoinSampo and its data, therefore, promote not only a paradigm shift in how cultural heritage knowledge can be effectively disseminated, but also in what kind of cultural heritage data institutions should aim to create today. This includes not only records of individual objects made "worthy" of being physically archived because of their age or rarity, but of all manner of archaeological finds, even of common objects, because as aggregate mass data they may reveal completely new patterns that are of great relevance to understanding our shared past.

This paper is partially extended from a demo paper [13], and is structured as follows: First we present a summary of the current state-of-the-art in terms of European public finds data services and portals, and numismatic DH infrastructure. This is followed by a discussion of the CoinSampo data, data model, and a description of the web application. We demonstrate

[1] https://coinsampo.ldf.fi
[2] https://www.ldf.fi/dataset/coinsampo
[3] https://www.w3.org/RDF/
[4] https://www.w3.org/TR/rdf-sparql-query/
[5] The endpoint can be queried at https://ldf.fi/coinsampo/sparql. The endpoint is set up using Apache Jena Fuseki: https://jena.apache.org/documentation/fuseki2/.
[6] https://www.ldf.fi/
[7] Project homepage: https://seco.cs.aalto.fi/projects/diginuma
[8] https://loytosampo.fi/en

CoinSampo's potential as a platform for conducting scientific research and for effectively disseminating complex archaeological and numismatic material. Finally, we conclude with a critical reflection on lessons learned during research.

2. Related work

A considerable amount of work has been conducted in the recent years on developing platforms and data services for European cultural heritage data, with recent transnational efforts including the European Cultural Heritage Cloud[9] and the ARIADNEplus[10] [14] portal. ARIADNEplus is a pan-European research infrastructure and aggregation project for all archaeological data, but coin finds data (as a major category of archaeological finds) naturally forms a substantial part. Targeting numismatic knowledge, Nomisma.org[11] [15] is a collaborative international project that aims to provide the necessary LOD ontologies for representing numismatic concepts. Nomisma data has been used to create multiple web applications, such as the Seleucid Coins Online[12]. However, Nomisma is currently mainly focused on the classical era, which limits it's applicability to Finnish data.

Online portal have been established in several European countries for opening specifically archaeological public finds data, notably in Belgium (MEDEA[13]), the Czech Republic[14], Denmark (Digitale Metaldetektorfund, DIME[15]), England and Wales (PAS[16]), Estonia[17], and the Netherlands (PAN[18]). Each has, invariably, approached the dissemination of the finds data from local perspectives, and according to the prevailing national cultural heritage management priorities. These in turn have shaped the technological solutions adopted. In the Netherlands, for instance, considerable attention has been paid to developing object typologies, with illustrated reference guides to artefact types built into the portal interface [16]. This is being develop as an important scientific and citizen science resource on its own right, which may assist heritage professionals by "crowd-sourcing" object identification and recording. In Estonia the finds portal permanently obfuscates the locations below a sub-regional level of *c.* 100 km2. Whereas in some other countries (including Finland) the precise findspot location of an object is published once it has been processed by heritage professionals, in Estonia this is not done because of heightened concerns over looting of vulnerable archaeological sites [6].

A certain amount of tailoring to local circumstances is therefore the norm. On a broader conceptual level, however, the above finds portals offer little by way of powerful tools, beyond simple map applications, to visualize important patterns and archaeological phenomena in the data. This is typical of cultural heritage data services at large. These tend to be build upon a paradigm derived from the traditional knowledge representation scheme of the field: printed

[9] https://data.europa.eu/doi/10.2777/64014
[10] https://ariadne-infrastructure.eu
[11] http://Nomisma.org
[12] https://numismatics.org/sco/
[13] https://vondsten.be
[14] https://amcr-info.aiscr.cz/?page=pas
[15] https://www.metaldetektorfund.dk
[16] https://finds.org.uk
[17] https://leiuatlas.ee
[18] https://portable-antiquities.nl

museum catalogues. Objects are opened to the user as individual entries, often richly described but not very effectively located in a larger context that could be provided either by the contents of their collection as a whole or by wider LOD resources (cf.[1]).

The potential for "big data" analysis of public finds, however, has been explored and exploited in archaeological research already for some time [17, 18, 19]. CoinSampo deploys a series of data visualization tools developed to fit the archaeological particularities of the dataset, as well as links to external resources relevant for understanding the rich historical phenomena represented by the numismatic material. It presents a model for democratizing not only access to digitized cultural heritage, but also to data analysis more generally.

3. Data

The CoinSampo KG was created using data collected at the Finnish National Museum based on reports sent by members of the public who have found old coins, usually through metal detecting. The data was collected between 2013 and 2023 as a tabular Excel file with the aim of recording all coin finds reported during that time period in Finland. With some exceptions, this material consists of coins that are more than 100 years old and thus protected by the current Antiquties Act[19]. The original tabular data includes the following fields for each object: find municipality; more exact location of the find site such as the village; northern find coordinate (y); eastern find coordinate (x); context of the find such as field or forest; authority; denomination; mint; country; period; material; numismatic type; earliest possible date of minting; latest possible date of minting; finder name; date of finding; free-text field for additional notes; ascension (i.e. FHA national collection) number; weight. Because of privacy reasons and the European Union's GDPR legislation[20] finder information is not included in the public CoinSampo KG. The exact find coordinates of redeemed finds (generally medieval or older) that have not yet been fully processed by the FHA have also been omitted for reasons of protecting particularly vulnerable archaeological sites. Moreover, as soil finds some of the objects are in such a bad shape that exact definitions are impossible to determine even by an expert.

Initially the Excel file was used only to keep track of the finds. Before about 2015 finds were reported in various ways and without any standardized reporting platform. As the number of finds increased, it soon became evident that their handling had to be rationalized. All find reports were directed to a common e-mail address. In addition, return forms were introduced for finds not taken into the collections. In 2019 the Finnish Heritage Agency launched the Ilppari reporting service for all archaeological finds made by citizens. The online service has significantly increased the number of finds reported to the authorities, also providing more detailed coordinate information on the find location. Over the last five years, the recording of coin finds has developed accordingly, enabling systematic data processing.

During the development stage for CoinSampo, the Excel file was improved and expanded several times. Information was added, for example, on materials and dating, as well as hierarchical information on the coins' region of origin and mint. Furthermore, ontological work and data cleaning was conducted with the aim of removing typos and parallel concepts. The

[19]https://www.finlex.fi/fi/laki/ajantasa/1963/19630295#L2
[20]https://eur-lex.europa.eu/eli/reg/2016/679/oj

conversion process of the data to RDF format was made by a repeatable Python script. In the conversion process the data was first converted using literal values, and object values were added in a second phase. This means that the original literal forms of the terms used in the Excel file are retained in the CoinSampo KG.

The CoinSampo Data Model (CSDM) was created to represent this data. The central properties of CSDM are given in Table 1. The namespace used for CSDM schema is `<http://ldf.fi/schema/coinsampo/>`. The examples in this paper use prefix `cs` for this namespace. The table also lists the number of coin finds with that property and gives the equivalent properties in the Nomisma.org ontology (namespace `<http://nomisma.org/ontology#>` prefix `nmo:`). As a data model [20] CSDM is mainly focused on the specific needs of the Finnish coin data, as opposed to an universal ontology such as that produced by Nomisma.org, which is meant for more generic use. CoinSampo also uses some properties derived from Simple Knowledge Organization System SKOS[21], FindSampo, and Basic Geo[22]. For example, the labels and broader concept relations are expressed with SKOS and the coordinates using Basic Geo.

Property	C	num.	Nomisma	Explanation
cs:denomination	1	18342	nmo:hasDenomination	Face value of a coin.
coins:context	1	18342	nmo:hasContext	Find context of a coin.
coins:period	0..1	18323	nmo:hasProductionDate	Production period of a coin find.
cs:material	0..1	18304	nmo:hasMaterial	Main material of a coin.
cs:municipality	0..1	18302	nmo:hasFindSpot	Municipality where a coin was found.
cs:country	0..1	18232	nmo:hasMint	Country or region where a coin was minted.
cs:authority	0..n	13394	nmo:hasAuthority	Authority (ruler) in whose name a coin has been issued.
cs:mint	0..1	13311	nmo:hasMint	The place where a coin has been minted.
cs:numismatic_type	0..n	2151	nmo:hasObjectType; nmo:hasPeculiarity; nmo:hasScholarlyName	Refers to possible miscellaneous numismatic type of a coin.

Table 1
Main object properties in CoinSampo data model, with their corresponding Nomisma.org properties.

To represent the concepts in the data, multiple light weight ontologies or vocabularies were created from the data for concept types such as authorities, mints and denominations. These vocabularies are in this paper referred mainly as “facet ontologies”. These facet ontologies include hierarchies and are linked to external resources, mainly Wikidata [21], where possible. Wikidata has been used to enrich the ontologies in various ways. While the facet ontologies are

[21]https://www.w3.org/2004/02/skos/
[22]https://www.w3.org/2003/01/geo/

created mainly for the purposes of exploring and visualizing the CoinSampo KG (eg., by using hierarchical facets or showing coordinates of mints on maps), they could also be used as a basis for vocabularies of similar data sets, such as coin finds from neighbouring countries.

Facet ontologies were created for find municipalities, authorities, mints, countries, denominations, contexts, materials, and numismatic types. This was done by outputting all the terms used in each of these fields as CSV files, and then going through them systematically to remove duplicates and correct errors, so that only the desired ontology of concepts and their preferred labels remained with each line corresponding to a single concept. The URI of each concept was created using the Finnish label as the local identifier. Duplicate terms and common incorrect forms were retained as hidden labels in their own column for each concept.

The facet ontologies were mapped to Wikidata and/or the Finnish ontologies [23] MAO/TAO (Ontology for Museum Domain and Applied Arts) or YSO (General Finnish Ontology). These mappings were mostly done manually in CSV files. Wikidata was queried with SPARQL to enrich the facet ontologies in a number of ways, including extracting coordinates, images, and descriptions. Mappings to the Nomisma.org ontology and the Numista.com service were also extracted from Wikidata for mints and authorities. All the instances in facet ontologies include English labels in addition to Finnish ones. Many of these were added automatically through Wikidata or YSO mappings, though in some cases a translation had to be added manually. Hierarchies were also defined in the CSV files for concepts using a separate column[24]. Finally, the facet ontologies were converted to RDF based on the CSV files using a Python script. The classes of facet ontologies, number of instances, and explanations are given in Table 2.

Class	Num.	Explanation
coins:Municipality	242	Municipality, e.g., a town.
coins:Authority	193	Authority such as a ruler.
coins:Denomination	168	Face value of a coin.
coins:Mint	160	A place where coins have been minted.
coins:Context	49	General context of the find, such as “field”.
coins:Country	41	A country.
coins:Numismatic_type	34	Term describing the general properties of numismatic object.
coins:Period	9	Historical time period.
coins:Material	6	Material of manufacture.

Table 2
Main classes in CoinSampo data model and the number of their instances in the facet ontologies.

A major difference between Nomisma and CSDM is that in Nomisma properties – such as material, denomination and authority – are generally not expressed for individual coin objects. Instead the objects refer to a “type series item” resource that contains information on the material, denomination, and other properties related to that specific type of coin. Whether or not to follow this was the major modeling question when CSDM was being developed. It was

[23] For Finnish ontology service see https://finto.fi/en/.
[24] For municipalities a slightly modified hierarchy from the Finnish place ontology YSO places (https://finto.fi/yso-paikat/en/) was used.

decided that it would be too much work to develop the necessary ontological infrastructure demanded by the “type series item” approach to cover all coin finds. This typological information already existed in the CSV files in a format that expressed the data separately for each coin. Adding the type series item resources would add more work. While the memory requirement is larger when material, denomination, etc., is expressed separately for each coin, SPARQL queries perform faster when querying information for coins using our approach because the property paths are shorter.

When comparing the CSDM to Nomisma, it should be noted that Nomisma tends to include properties for much more detailed description of coins. Nomisma also includes properties such as nmo:hasIconography and nmo:hasCorrosion that can be used for much more detailed structured description of coins, which the CoinSampo data lacks. Notably, in CSDM the property cs:numismatic_type combines multiple different properties from Nomisma, since it is used for a somewhat miscellanious set of characteristics that were not deemed worth the effort to make a detailed semantic distinctions for. On the other hand, CSDM includes separate properties for mint and country or region of origin. This is because while the exact mint cannot always be determined due to the fragmented nature or the poor state of preservation of a given coin, it is usually possible to identify the general geographical area in which the coin was minted. From a research perspective it was desirable make a clear semantic distinction between these two related properties.

Nomisma.org ontology does not currently cover well the concepts required to describe Finnish coin finds. Out of the 160 mints in the CoinSampo data 44 currently have a mapping to Nomisma.org, and out of the over 18 000 individual coins only 210 are connected to a mint with a Nomisma mapping. For authorities, a Nomisma mapping exist currently for 34 out of the 193 resources, and only 146 individual coins have an authority that is mapped to Nomisma. The existing Nomisma resources for describing the authority or mint exist therefore only for around one percent of all the reported coin finds in Finland. This is largely because Nomisma’s ontological infrastructure of medieval and later coins has not yet been developed.

Finally, CSDM allows for uncertain or unclear concepts. These are defined as instances of cs:Uncertain_concept in addition to their other classes. CoinSampo facet ontologies currently include 17 such concepts. For example a number of historical coins found in Finland have clearly been issued in either Denmark or Sweden but the mint cannot be determined more precisely. In such cases a separate resource has been created, to represent the uncertain concept of, in this example, “Denmark/Sweden”. These resources are mapped to the Wikidata resource of all the possible individuals that the uncertain concept represents.

4. Web application

The CoinSampo web application [25] is based on the Sampo-UI[26] framework [22, 23]. The application works by creating SPARQL queries based on selections made by users and visualizing the data using various JavaScript libraries. As an application based on Sampo-UI, CoinSampo consist

[25] The source code of the portal is available at https://github.com/SemanticComputing/coinsampo-web-app and the portal can be tested at https://rahasampo.ldf.fi/en/.

[26] https://github.com/SemanticComputing/sampo-ui

of a front end mainly created using React[27] and a back end using Node.js[28]. The application can be deployed easily using a Docker container.

The application is built to apply the concept of faceted search [24]. The data can be explored and filtered using various facets representing entity properties. Coin finds can be filtered using facets based on authority, mint, period or other properties. Each facet shows the hit count for each individual selection. Facets are dynamic and the hit counts constantly update after a selection is made in one of the facets. Because of this user can avoid searches that would not return any results, and the hit counts offer further insight into data and help to explore it. The default language of the application is Finnish, but the application can also be used in English. The facet ontologies have English labels in addition to the Finnish ones, and the user interface can dynamically switch between the language of the concepts by changing the language tag in SPARQL queries (though the free-text "Notes" field is currently available only in the Finnish language). In addition to the perspective for coin finds the CoinSampo web application also offers search perspectives for searching and visualizing authorities and mints.

A basic use example of the application[29] is shown in Fig. 1. A user has made two selection using facets to filter the results. The period "18th century" has been selected from the Period facet, and the broader region of "South Karelia" has been selected from the find discovery Municipality facet. Because the municipality facet is hierarchical, the system selects all the sub-concepts (municipalities) belonging to "South Karelia". The result set consists of num150 individual coins, as can be seen in the top left corner. The default table view shows the most important information about each individual coin as a record row, with a separate column for each property. Each coin has their own instance page, which can be accessed using the hyperlink on the table. Similarly important instances in the CoinSampo facet ontology – such the authority "Peter the Great" or the period "18th century" – have their own instance pages.

The coins images shown in the table view are not of the individual coins themselves, as in most cases this data is not available. Instead, CoinSampo shows images of similar kinds of objects from the Finna[30] service. Image links have been retrieved using Finna's API[31] through creating search queries from coin properties such as authority, denomination, and material. Clicking on an image opens the relevant search results page in Finna in a new tab.

The results can also be viewed in various ways by selecting one of the visualization tabs. The visualization options include various types of charts and maps[32]. The Use case section, below, includes multiple examples of how these visualizations can be applied in analysis and knowledge discovery.

[27]https://react.dev/

[28]https://nodejs.org/en

[29]The examples are made using the desktop mode. CoinSampo can be used with mobile devices, and the interface makes some adaptations for small screen, but the application works best on using a computer with a larger screen.

[30]Finna service includes images uploaded by multiple Finnish museums. See: https://finna.fi/?lng=en-gb.

[31]https://www.kiwi.fi/display/Finna/Finnan+avoin+rajapinta

[32]The map in the example used in this paper is rendered using the Mapbox (https://www.mapbox.com/about/maps/) service which is based on the OpenStreetMap (http://www.openstreetmap.org/copyright. CoinSampo also uses maps provided from multiple other providers, such the National Land Survey of Finland.

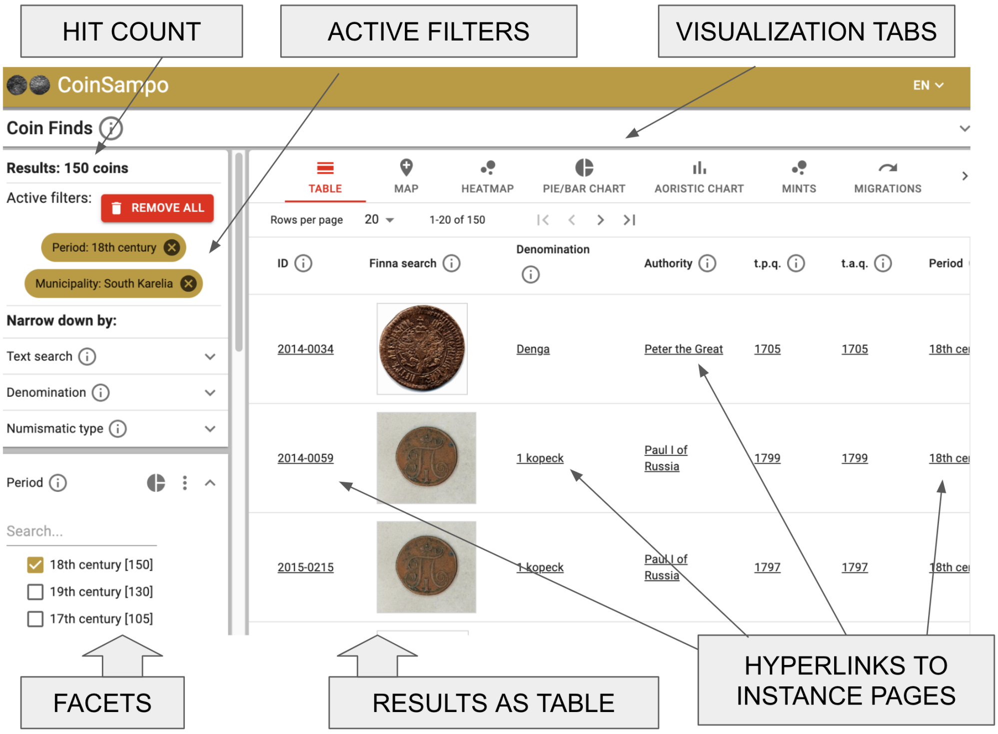

Figure 1: Image shows the basic logic of the CoinSampo user interface. A user has made selections using check box facets on the left and the result are shown on the right.

5. Use case

Coins from the Viking Age (here defined as 800–1150 AD) are well suited for demonstrating the various functions of the CoinSampo data service. In Finland, as in the rest of northern and eastern Europe, coins were at this time used as bullion and valued by their weight in silver. This means that the denomination or origin of a coin was of limited importance, although some coin types were certainly valued to a higher degree because of, e.g., their high silver purity. The circulation of coins was therefore particularly international, creating interesting contact patterns that linked vast areas in Europe and Asia. This was particularly so in Finland, where coins arrived from western Asia and the Mediterranean via the great river routes of modern Ukraine, Belarus and Russia, and over the Baltic Sea from Scandinavia, central and western Europe [25]. See, for example, Fig. 2 created using the "migration" visualization tab: the arcs connect the municipality of Hämeenlinna to the minting places of Viking Age coin finds reported there, arriving from as far away as modern England, Germany, Iraq and Uzbekistan.

Finds reported by citizens have considerably changed the research situation regarding the Viking Age coin circulation in Finland, creating a whole new body of material for understanding the region's pre-monetised economy. When Tuukka Talvio published his thesis on Viking Age coin finds in Finland in 2002, the material available consisted of slightly over 7000 coins. Most of these coins derived from hoards. Around 450 were recovered from excavated graves, and

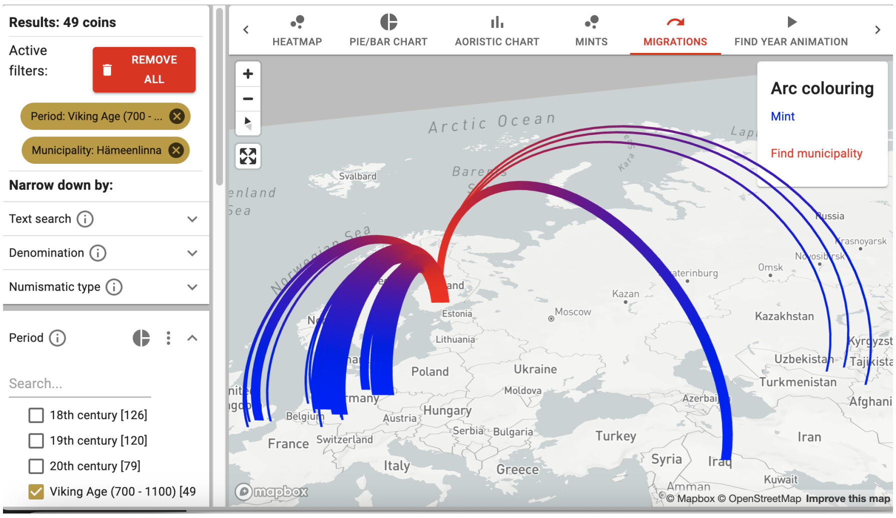

Figure 2: A migrations visualization of Viking Age coins recovered near the town of Hämeenlinna showing arcs between the find municipality and the places where the coins were minted.

only eighty from other excavations or as single finds[25]. The number of Viking Age single find coins opened by CoinSampo is 836, or more than ten times this number.

A numismatic single find is generally described as a coin without connection to other finds, whereas a cumulative find contains two or more singly found coins from a limited area [26]. Without further archaeological field work it is difficult to distinguish and categorize such finds with certainty. As Talvio has noted, casual single finds tends to be whole coins, while cumulative finds – possibly associated with dwelling sites – are more likely to consist of fragmentary coins. One third (280) of the Viking Age coins in CoinSampo are fragments. The earlier the coin, the more likely it is to have been cut into hacksilver and used as bullion. The high number of fragments likely reflects silver use in connection to settlements and other activity sites, some which may have been previously unknown. Previously, when coin finds mostly consisted of hoards and grave finds, this was not well understood. Considerable scientific research potential remains for work critically distinguishing and categorizing these different types of finds.

Because of the fragmentary nature of Viking Age coins in the Finnish finds material, it is not always possible to produce a complete definition with exact determinations for all attributes. For example, sometimes it is only possible to work out a general area of origin (e.g., "Germany") and not the exact minting place (e.g., "Köln"). Likewise in some cases it is impossible to date the coin more precisely than within a century. And as seen in Fig.3, authority is undetermined in more than half of of the entries.

It is nevertheless possible to extract a great deal of new information on the Viking Age coin economy in Finland from the CoinSampo data. Using the faceted search it is easy to screen different coin types. 327 (39 percent) of the recorded Viking Age coins are Islamic dirhams. The majority of dirhams found in Finland are either of Abbasid (mostly ninth century) or Samanid (mostly tenth century) origin. In his thesis Talvio estimated the number of Abbasid dirhams to be around 900, and of Samanid dirhams less than 300. Most of the Abbasid coin was derived

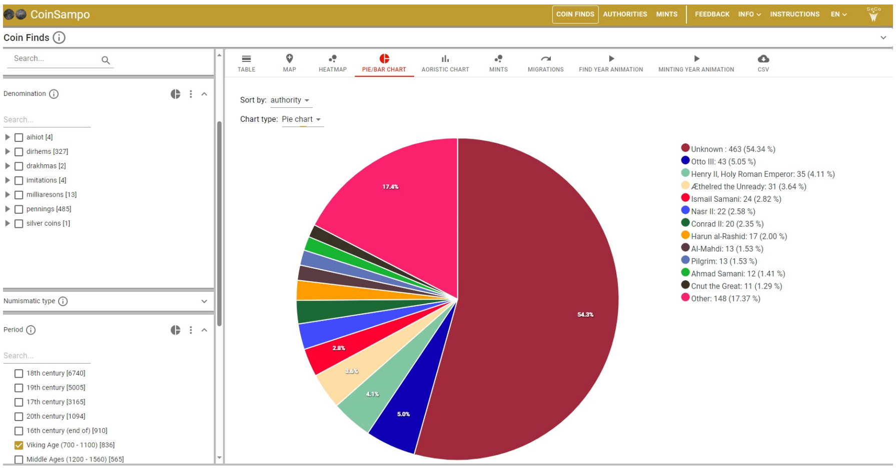

Figure 3: The automatically created chart shows the defined minting authorities of Viking Age coins added to CoinSampo. More than half are still marked as unknown.

from hoards in the Åland Islands, while Samanid dirhams were more commonly found in graves on the mainland.

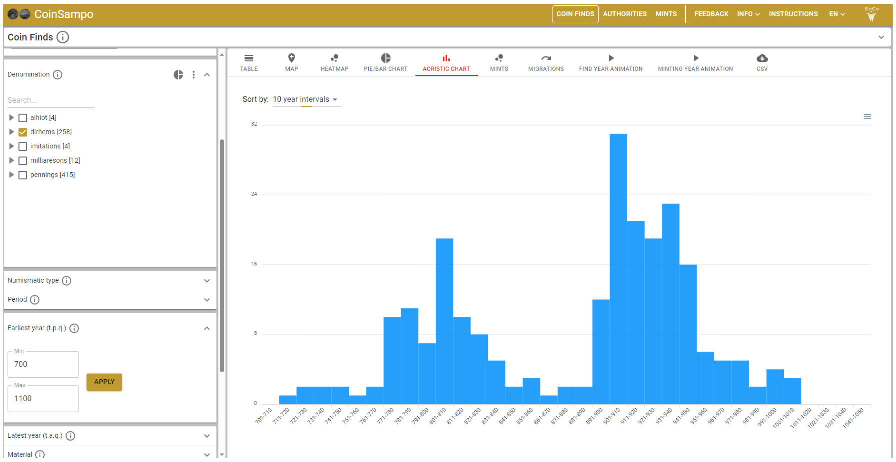

Figure 4: An aoristic chart showing the chronological distribution of dirhams in CoinSampo. The periods of high level of import are clearly visible.

As Åland is a self-governing region with its own Heritage Administration unit, only sporadic finds from there are included in CoinSampo. On the mainland, however, the number of dirham finds has increased significantly and provides a completely new view on coin imports. So far 103 Abbasid and 133 Samanid dirham finds have been reported. As seen in Fig.4, coins from the beginning of the tenth century are the most common. Significant quantities of this material was not previously encountered on the mainland. Most coins are (as noted above) fragments used as silver bullion and can probably be linked with Viking Age settlement sites.

The chronological and geographical distribution of the reported 485 western pennings does

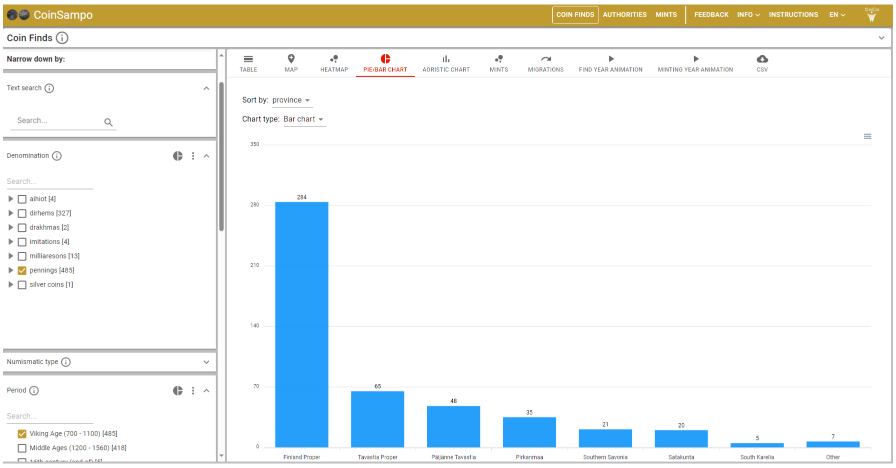

Figure 5: Bar chart showing the distribution of western pennings according to province.

not differ greatly from that of the older hoards. Most date to the last decades of the tenth century or the first half of the eleventh century. There are, however, an increasing number of coins from the second half of the eleventh century. These were previously known mostly from hoards discovered in eastern Finland, but not in the western part of the country [27]. The vast majority of the new western coin finds are from the south-western coastal region of Finland Proper (see Fig.5), which was undoubtedly the centre of Viking Age coin circulation as well as the area were most of this silver entered the country. By narrowing search parameters, it is possible to observe that finds from Finland Proper contain a higher proportion of certain generic German coin types as Otto Adelheid -pfennings and denars minted in Köln. By contrast the distribution of Anglo-Saxon (English) pennies and of the less common German coins is more evenly divided, which may suggest different import routes. Cumulatively this new evidence begins to shed light into such important but otherwise difficult to examine fields of research as Finnish prehistoric inter-regional and international travel connections.

6. Conclusions and future work

LOD can be used not only to publish collection data for humans to read (first generation systems) but also as data for analyzing collections using data-centric methods in DH (second generation systems) [28]. CoinSampo tests and demonstrates this possibility in a novel application domain: archaeological numismatics. Ontologies based on the concepts in the data and mapped to external resources are used to enrich the data, and to make it easier to search, visualize, and analyze it. We demonstrate how novel insights into collections data can be easily generated by anyone without further specialist training in statistical software. CoinSampo democratizes information about the past by making the data easy to access and examine, whether as individual records or as an interconnected whole.

The demonstrator is an example of how practical and usable applications can be built easily on top of SPARQL endpoints using the declarative Sampo-UI framework [23]. In addition to the demonstrator presented here, we are also developing a more generic version of the CoinSampo web application, which could be used to search and visualize any data that follows the Nomisma.org ontology. For example, [11] presents an early version of CoinSampo with international data.

A new data model was deemed the most convenient way to represent data in CoinSampo, though the properties and classes can usually be mapped to the Nomisma.org ontology without difficulty. Such mappings are useful when comparing local and international data. In many cases, however, Nomisma is missing the concepts required to describe Finnish coin finds. While certain simple cases, such as the material of manufacture, are straightforward to link to Nomisma, the required concepts for representing mints and authorities exist only for around one percent of the finds. Finnish coin finds (with only rare exceptions) are in European terms either medieval or later, and these post-classical periods are still being developed in the Nomisma.org ontology.

Very importantly, there is also a difference between numismatic data obtained from old museum collections – which often arrive from private collections or hoard finds, and where the coins are in comparatively excellent condition – and data obtained from individual finds recovered from the soil, usually from industrially ploughed fields. This difference is seen in the quality of the available data. The latter are more likely to be fragmented and corroded, and any data models and ontologies developed around them must take into account the fact that exact determination of object properties may be difficult or impossible.

The broader research topic that this links to is the difficulty in modelling complex and often uncertain cultural heritage information. Most archaeology deals with spatially and temporally uncertain or "fuzzy" data, or with data where precise values cannot always be assigned to key properties (here authorities, minting places, etc.). Knowledge organisation systems (such as ontologies) arguably arise from pragmatic needs to model real world phenomena [29], and therefore are a response to the particular needs, circumstances and material around which they are constructed. In this context the development of a universal system, one that would reach beyond its original source material, can be a particularly challenging aspiration.

This is highlighted in the CoinSampo research case, which brings in a new kind of source material to digital numismatics (metal-detected soil finds), one which is typically damaged or fragmentary. A knowledge organization system based on a different preconception of the character of the base data – such as the Nomisma.org ontology, despite aspiring to be a universal system within its domain – may therefore find it difficult to incorporate. CoinSampo offers some examples of how to represent such data semantically, but the issue remains a challenge.

There is, therefore, a great deal of interdisciplinary and collaborative research left to be do in order build semantic infrastructures that allow for a greater reuse and interoperability potential in archaeological and numismatic, and more broadly in cultural heritage, data management at an international level. This also includes effectuating a paradigm shift in how the act opening cultural heritage data is conceptualised, towards a more integrated view that sees the contents of collections not as a limited selection of discrete objects but as a connected body of material that, when considered together, can tell more about the past than when apart.

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