Exploring Medieval Religious Material Culture Using the ARCH-ON Ontology

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Abstract

This paper presents initial results of developing an ontological framework for semantically describing medieval ampullae. The work is designed to simplify analysing data relating to medieval ampullae and as a test case for the ARCH-ON ontology-based classification scheme for archaeological artefacts. ARCH-ON-Sampo, a demonstrator application for exploring and visualising archaeological cultural heritage, is also presented. This paper also presents initial results of analysing the ampullae in the data of the British Museum's Portable Antiquities Scheme using the ontological framework and the analytic tools of the ARCH-ON-Sampo.

Keywords

data harmonization, Linked Open Data, ontologies, archaeology, history of religion

1. Introduction

A major challenge in the international digital Cultural Heritage (CH) landscape is bringing together large legacy artefact inventories for computational work that have been compiled in different countries, or even within different institutions in a given country. Though drawing on considerable scholarship that encodes period, regional or culturally specific archaeological information, this data is currently poorly captured as structured and linked data on a transnational scale. The ARCH-ON (Archaeological Ontologies[1]) [1] project proposes a novel semantic scheme to classify a diverse range of archaeological objects. ARCH-ON classification framework is based on artefact *attributes*, and aims to enhance the semantic interoperability and research potential of transnational archaeological data reservoirs.

Archaeology has long relied on classifying artefacts into *typologies* based on their form and other physical features [2]. This is useful for categorizing and investigating artefacts. Typologies can be used, for example, to date artefacts or to explore spatial processes such as the spread of certain cultural, social or economic conventions. However, this traditional approach has multiple limitations [3, 4, 5], which we group into two broad categories for the purposes of this discussion.

From a humanistic research perspective, any application of typology-based Knowledge Organization Systems (KOS) in archaeology encounters several major challenges. Typologies are constrained by the hierarchical organization of selected artefact traits and the requirements of specific research questions or purposes guiding the typologist at the time of their creation. Consequently, typologies can fossilize outdated assumptions about past societies and the wider context of the specific material culture they describe. The hierarchical framework of relationships described by a typology is moreover inflexible, and

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[1]ARCH-ON project homepage: https://seco.cs.aalto.fi/projects/arch-on/

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as more information and knowledge (including new archaeological object finds and related discoveries) is generated, the typology can be difficult to update.

These objections are amplified by the historical reality that the framework of typologies as the dominant archaeological KOS was invented long before the current technological regime of digitized or digital-born CH data. Therefore, classifications produced in the context of modern nation-states can be suboptimal for large-scale transnational data harmonization [3, 1]. Moreover, the currently prevailing KOS for archaeological objects is not optimized to exploit the paradigm shift that occurred when "ontologies" [6] were introduced in Artificial Intelligence and used in Semantic Web research. The novel idea was to *define* categories in a computer "understandable" way to facilitate reasoning and computational applications, such as analyzes in Digital Humanities (DH) research.

The ARCH-ON project and the design of the ARCH-ON ontology are presented in more detail in [1]. This paper expands the discussion and presents the initial experiences in creating vocabularies and a web application called ARCH-ON-Sampo for a practical use case based on ARCH-ON ontology. Examples of using the enriched data and the application to help solving humanities research questions are also discussed.

2. Applying the ARCH-ON ontology

To address the challenges raised above, the ARCH-ON framework [1] describes artefacts and artefact classes in semantic terms by modelling their relevant orthogonal attributes (aspects, features). This idea is related to the notion of faceted classification in information science, where literary works are classified along several dimensions, such as time, place, and form. This stands in contrast to a single large, rigid classification framework, including standard archaeological typologies but also such KOS as the Dewey Decimal and Library of Congress Classification. Faceted classification makes it possible to use methods of faceted search and browsing to access data from multiple perspectives, and integrate search seamlessly with tools for DH analyses [7]. This approach for modelling information on individual observations has been successfully tested in other fields of scientific inquiry, such as representing ecological information based on insect traits [8].

Our project is inspired by various initiatives to develop data model standards for different types of archaeological or related CH use cases. These include, notably, the field of numismatics, where the existence of (in comparative terms) highly detailed and internationally shared standards for describing coins and related objects has laid the foundation for the Nomisma.org ontology and LOD initiative[2] [9]. In Europe ARIADNEplus [10] project and its Ariadne portal[3] harmonises European archaeological records. Another important initiative has been the development of a CIDOC-CRM-based data model for archaeological fieldwork[4]. A networked approach to investigating variations and relationships among early medieval European dress accessories – developed by dissecting the object into its constituent parts or "components" – has likewise been successfully tested [5], preparing the theoretical and methodological ground for approaching other items in a similarly attribute-based manner. Our project continues this work on archaeological semantic modelling. The ARCH-ON data model is presented in more detail in [1]. The underlying data model re-uses the CIDOC CRM ontology, the Dublin Core metadata terms[5], and the FOAF vocabulary[6]. The namespace for classes and properties in ARCH-ON ontology is `<http://ldf.fi/schema/archon>` which is shortened with prefix `archon:` in this article.

To test and develop the ARCH-ON ontology, we model medieval ampullae (pilgrim flasks) and their complex decorations as a case study. Instead of using a typological classification, three aspects of artefacts (ampullae) are considered: intrinsic characteristics (e.g., material, measurements), extrinsic characteristics (e.g., collections data, dates assigned to the object, recovery location), and design elements and interpretative characteristics (e.g., religious motifs and their meanings).

[2]Nomisma initiative: https://nomisma.org
[3]https://portal.ariadne-infrastructure.eu/
[4]See, e,g. https://cidoc-crm.org/crmarchaeo/, also applied in http://openarchaeo.huma-num.fr
[5]DCMI Metadata Terms: https://www.dublincore.org/specifications/dublin-core/dcmi-terms/
[6]FOAF Vocabulary Specification: http://xmlns.com/foaf/spec/

We have selected medieval ampullae as a test dataset for the ARCH-ON ontology and data service demonstrator because they exemplify the value and potential of semantically describing a type of material culture object that is widely encountered in a transnational European context. Yet, despite this ubiquity, they remain relatively poorly understood, opening opportunities for creating new information and interpretations linked to a range of archaeological and social processes [11]. Ampullae (see Figure 1) are small, typically leaden, containers used by pilgrims to transport holy liquids, such as water and oils, from religious sites. Not only were these liquids found to cure and protect, but the vessels themselves might be prized as secondary relics [12]. Although ampullae were used throughout the medieval period, those dating between about 1350 and 1550 are of a particular type (studied here): a flattened vessel, with a more-or-less rounded body and narrow neck. Their protruding handles could be used to suspend the object, presumably about the neck, or otherwise fixed to clothing for display, but also (potentially) for display about the home. Many recovered by metal-detecting on arable farmland are found broken, presumably to release their liquids, perhaps as part of ritual activity in the medieval landscape [13, 14]. Besides their varied forms, of which the chronological development remains a mystery, ampullae have been of prime interest to archaeologists because of the designs they bear on either side [15, 16]. About half have a shell motif, itself an emblem associated with pilgrimage, specifically to the cult centre associated with St James the Great at Santiago de Compostela, Spain. Otherwise, these designs vary, and can include crowns, flowers, hearts, letters, etc. These devices may be completely random or personal choices of their makers, but more likely reflect an association with a particular shrine [15, 11]. These links are hard to investigate through a physical study of the object alone, and necessitate computer-aided programming to better understand relationships between objects and places.

As a proof of concept, 480 ampullae from across England and Wales in the British Museum's Portable Antiquities Scheme database (PAS)[7] database recorded 2020–2024 were classified along a variety of orthogonal dimensions, and the result was transformed into LOD conforming to the ARCH-ON data model. The data will be published in autumn of 2026 on a SPARQL endpoint hosted on the Linked Data Finland platform [17], excluding certain information, such as coordinates of some finds, that cannot be made public according to PAS terms.

ARCH-ON ontology is designed to provide classes and properties for modelling data in an interoperable manner. However, describing real data also requires instances of classes that form controlled vocabularies. For the PAS ampullae case, we created multiple new vocabularies. These include both very clear and generally agreed concepts with existing vocabularies such as administrative regions of England to represent find locations. Some vocabularies were derived from existing archaeological classifications, such as the Spencer [15] types for classifying the shell designs on ampullae, which also relates to their shape. However, some vocabularies were created based on the data and its requirements. For this case study, the most complex bespoke vocabulary is that of visual elements required to represent the motifs in the ampullae with 67 unique concepts. A hierarchy of visual elements has also been defined. For example, "flower" is a broader concept of "fleur-de-lys" and of "daisy wheel".

Some of the hardest questions in this work have dealt with determining the relation between the "primary" and "complex" motifs [1]. For example, should there exist concepts such as "Letter W, crowned", or should there be (in that case) only two separate elements "Letter W" and "Crown". Such a motif combination may have a specific meaning in the vocabulary of religious representation that is separate from its components. It has been proposed, for example, that a crowned letter W is associated with the Virgin Mary [13, 15]. The solution used here is to accept that such examples are "complex" visual elements that also consist of two or more simpler (or "primary") elements, when these latter have established use (e.g., "Letter W" and "Crown" also occur separately). However, complex elements have a semantic connection to simpler elements of which they consist, making searching based on them easier.

Our approach recognises that there are potentially endless aspects of physical objects that could be modelled. Semantic description therefore responds to humanistic research questions linked to use cases (see below), which require the creation of pragmatic categories. Additionally, it considers future harmonisation potential with other ampullae (or more broadly CH) datasets, and supports

[7] PAS database is available at: https://finds.org.uk

data exploration to expose previously unseen patterns. In contrast to typologies the systems retains considerable flexibility for creating new concepts in light of new research questions and needs.

The data was received from the PAS database as a tabular file. The ampullae data was then manually enriched with data on visual elements as well as physical modifications (e.g., piercing, folding) by archaeology small finds experts, as these relate to ritual reuse of the objects. The data was converted to RDF format using a Python script based on RDFLib[8] library. Table 1 presents the initial figures of how many instances of the central classes have been used in this case. The exact numbers may still vary, but this will give a rough idea of the vocabulary work required.

Class	Num.	Explanation
archon:Completeness	6	Completeness of overall shape.
archon:Spencer_type	2	Spencer's classification of ampullae designs.
archon:Modification	10	Secondary treatment, e.g., piercing.
archon:Modification_location	6	Location of a modification or damage.
archon:Visual_element	67	Visual element

Table 1
Central classes used to describe the ampullae and the number of their instances in PAS ampullae vocabularies.

To demonstrate the use of the ontology and to help analyse the data on ampullae, a web application[9] was created on top of the SPARQL endpoint using the Sampo-UI framework [18]. The application supports faceted search [19] integrated with tools for DH analysis and data visualization. It was created to demonstrate the use of ontology, but also as a tool to help with exploring the data and to help answer humanities research questions. ARCH-ON-Sampo is partially based on our previous work on FindSampo and CoinSampo[10] [20].

Faceted search is implemented with SPARQL queries created by the web application. The search is limited to resources in the KG with `rdf:type archon:Archaeological_object`. Each facet represents a property path starting from an instance of `archon:Archaeological_object`, with possible other restrictions when required. The facets then represent an aspect of the object, such as its completeness, its motifs, or its assigned dating. Facets can be used to limit the search group, and each facet is updated after each selection, showing the available selections in the current hit group with hit counts for each selection. There are also simpler filters for literal values, such as weight or width.

Figure 1 shows a screenshot of the demonstrator. Ampullae can be examined using the facets on the left, which pertain to the location where they were recovered and their religious visual elements – that may refer to saints' cults and pilgrimage sites – used in their decoration. The result set can be visualized on the right using tabs for a table, statistical charts, a map, and a heatmap. The facets on the left can be used to filter results. Here, the Heatmap tool has been set to display the distribution of ampullae with floral motifs (see Figure 1 on a map[11], and below). The user has selected all ampullae with a flower motif including sub-concepts, such as quatrefoil, using a hierarchical facet. Facet hit counts can also be used to provide insight into the data. For example, in Figure 1 it is easy to see from the facet hit counts that quatrefoil is the most common floral motif with 38 ampullae.

The use of hierarchy is a simple example of inference that can be potentially performed using SPARQL queries. In figure 1, the user interface has used SPARQL query to get the results and infer hierarchy in facet. The query uses `skos:broader`[12] and the property path modifier `*` to find all the sub-concepts of the selected visual element as shown in the query excerpt below that is generated by the user-interface based on the facet selection. In the example query, `?visualElementFilter` variable

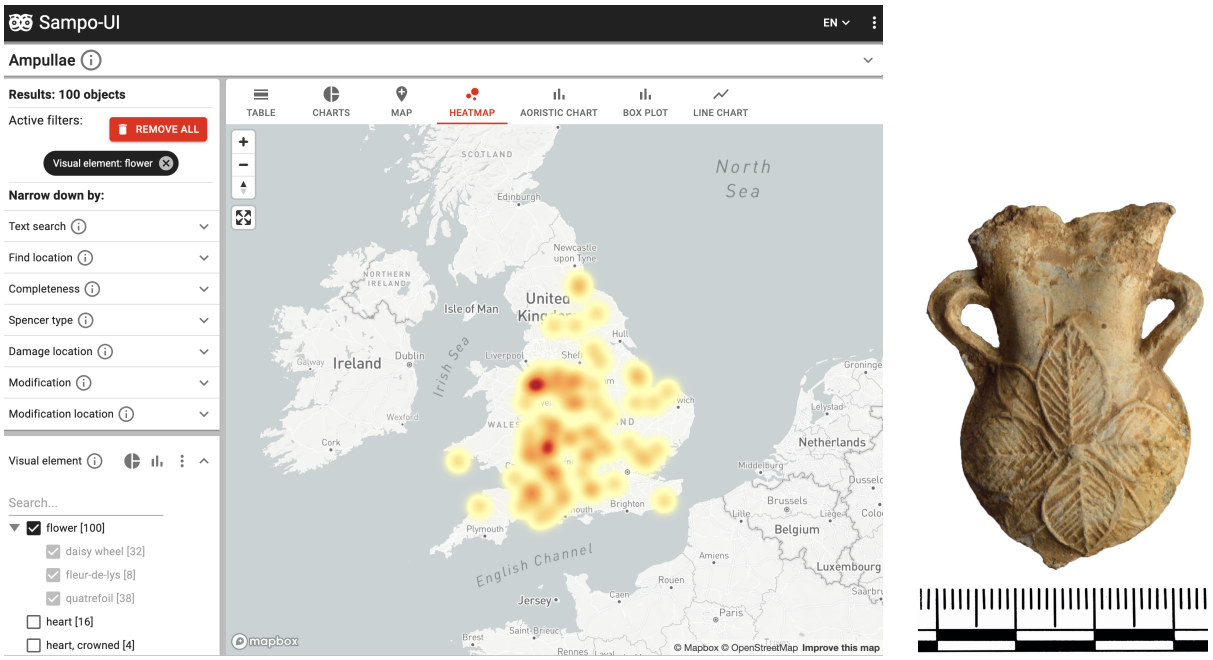
[8]https://rdflib.readthedocs.io/en/stable/

[9]The source code of the application is available at https://github.com/SemanticComputing/archon-web-app.git. The application is a work in progress and is planned to open online in autumn of 2026 at archon.demo.seco.cs.aalto.fi.

[10]The portals are online at https://dev.loytosampo.fi/en/ and https://coinsampo.ldf.fi.

[11]The user interface generates the map based on data from OpenStreetMap (http://www.openstreetmap.org/copyright) using the Mapbox service (https://www.mapbox.com/about/maps).

[12]SKOS Simple Knowledge Organization System https://www.w3.org/2009/08/skos-reference/skos.html.



(a) ARCH-ON demonstrator

(b) Ampulla

Figure 1: (a) Screenshot of the demonstrator showing the spatial concentration of ampullae with floral motifs as a 'heatmap'; (b) A late medieval ampulla (or pilgrim flask, PAS record ID GLO-CAD658) displaying a quatrefoil flower on one side. Image credit: The British Museum's Portable Antiquities Scheme.

is given the resource representing visual element "flower" as its value. The variable `?id` represents the searched objects. The property path from `?id` to `?visualElementFilter` selects all objects with motifs representing visual elements that have property chain of 0 or more `skos:broader` properties leading to the resource representing the flower visual element. So in other words, objects are selected that include a motif with a visual element that is either a flower or a concept that is somewhere below the concept of flower in the hierarchy defined using `skos:broader` properties.

```
VALUES ?visualElementFilter { <http://ldf.fi/archon/visual\_elements/v\_flower>  }
?id archon:has\_design\_element/archon:has\_visual\_item/skos:broader* ?visualElementFilter .
```

3. Exploring the Data

The ARCH-ON data model and faceted data service are designed to democratize and empower rapid exploration of archaeological records by anyone, without training requirements [21]. The following use cases are presented as general examples of how the data on ampullae motifs and other attributes could be studied to generate new information and interpretations.

First, the faceted search combined with the data visualization tools makes it easy to investigate interesting spatial or statistical patterns in the data. As noted, ampullae as pilgrimage souvenirs can inform us of previously unknown local and regional cult centres and shrines. A simple example is the motif "letter H". The count in the visual element facet shows that it occurs only four times in the dataset, suggesting that it is an unusual but not unique sign; the assistive visual element facet shows that the letter is always paired with the shell design on the other side. In a classical typological list the descriptions for all the available types would have to checked for the presence of this letter (and its possible motif combinations), but here this identification can be done quickly. The Charts tool indicates that the shell design is always of Spencer type 2, which can be visually verified in the Table view. All four ampullae were found in the county of Lincolnshire. This spatial distribution and the regularity in the morphological features in the group strongly suggest a single source for the finds – likely, a shrine of local importance somewhere in or near Lincolnshire (see also [11]). Armed with this information,

a researcher interested in local religious practice could turn to further sources of evidence, such the closer archaeological landscape contexts of the finds, or the dedications of local medieval churches. Perhaps significantly, there are 17 medieval churches dedicated to St Helen in Lincolnshire, making her one of the more popular local saints.

A second example dealing with a more complicated data distribution could be a comparison between the "shell" motif (n=202 records) and a floral ("flower", "quatrefoil", "daisy wheel", "fleur-de-lys"; n=100 records) motif. As noted above, these are the two most common types of motifs encountered on English ampullae. Various shell designs on one side of ampullae (as well as on other pilgrim signs) were used as a visual reference to pilgrimage across Europe. The floral motifs are rarer, but still internationally encountered (e.g., in Denmark: [12]). The two design motifs usually fill one side of the ampulla in a manner similar to the obverse or "portrait/effigy" side of a coin. In England, finds with both motifs are encountered all over the country in a manner that at first glance seems completely interspersed. The facility to select and compare major trends in distribution patterns using the Heatmap tool, however, quickly reveals a clear geographic division: the weight of the shell motif ampullae distribution lies in the east (focussed particularly in the county of Lincolnshire) and that of the floral motifs in the west (Figure 1). This pattern could reflect regional trends in religious symbolic representation, perhaps connected to local saints' cults or influential religious foundations.

Further processes emerging from the geographical distribution of ampullae can be examined using, for example, the Line Chart and Box Plot tools to visualize the spread of ampullae "weight", "length" and "width" dimensions for complete and therefore comparable objects (Table 2). On average, those recovered from northern England (regions of North Yorkshire and Humber, North East and North West) are markedly heavier than those across the dataset in general. South-western finds are slightly lighter in average, despite being somewhat larger. Ampullae (like almost all PAS finds that do not legally qualify as Treasure and therefore are unlikely to be subsequently acquired by museums) are typically only visually assessed for their material composition, and in this case all have been identified (on the basis of "white metal" appearance) simply as made of "lead alloy". Recent portable X-ray fluorescence (pXRF) element analysis of a sample of ampullae recovered in eastern England, however, has shown that ampullae are typically made of more or less pure lead or tin, and only rarely of an alloy [22]. Given lead is *c.* 50 percent heavier than tin and was historically cheaper, the diverging measurement sets suggest novel information on a differing mix of material and manufacturing traditions in different parts of England. Most likely these can be linked to sources of ore, as lead was mined in medieval Yorkshire [23], and in the South West of England the counties of Cornwall and Devon were tin production regions of international importance [24].

Region or cult centre	Number	Mean weight (g)	Mean length (mm)	Mean width (mm)
All of England and Wales	480	44.98	49.90	32.23
Yorksh. and Humber, NE, NW	45	51.91	48.83	33.72
SW	35	43.72	52.46	32.12
Walshingham	18	38.34	49.00	30.27

Table 2
Measurements for all complete ampullae, a selection of geographical regions, and those associated with the major Marian pilgrimage centre at Walsingham, Norfolk.

Moreover, it may be notable that ampullae linked to the shrine of Our Lady of Walsingham, Norfolk, are lighter again. Walsingham was the second most important pilgrimage destination in medieval England after Canterbury, and several scholars have robustly argued that several motifs are exclusively associated with the cult centre (the "arrow", "flask/vial" and "letter R, with staff" motifs [13, 14, 11]). The relative lightness of the Walsingham ampullae could be due to a particularly strong preference for the more expensive tin – which has a more silvery and therefore luxurious appearance – for aesthetic reasons and in line with certain higher-status display items. Alternatively or additionally, the metal casting techniques used at Walsingham could be more skilled, leading to smaller wastage of the metal

by the craftsperson, as the goal was to create a hollow metal pouch with relatively thin walls [22, 25, 16]. Statistical patterns extracted from the ampullae evidence could therefore be linked to a wide variety of important historical processes regarding regional religious culture, economic developments, the presence of mining industries and trade networks, and the professionalization of crafts workshops.

4. Conclusion and Future Work

The ARCH-ON ontology and data service framework allows for a more powerful and multi-perspective investigation of archaeological object data than offered by current classification systems and web services built on them. Future archaeological work is needed to test and verify the observations discussed above, but our example showcases data exploratory applications that are more fine-grained than those allowed by the standard typological KOS for material culture. While these samples are still relatively small, such results can be used, to identify potential groups of objects for later (and much more labour- and resource-intensive) scientific material analysis.

One promising avenue of further research is to consider international datasets. In the specific case of ampullae, relevant data is available through the Kunera database[13] of medieval European pilgrim objects, but the approach can flexibly accommodate diverse types of CH data. Further semantic work is therefore required in creating, mapping, harmonizing and linking concepts and attributes. In our case, creating a vocabulary of visual elements for the ampullae required making judgements on what constitutes a proper visual element. It can also be difficult to determine visual elements from imperfectly preserved artefacts. Modelling the resulting uncertainty is an interesting question for future work.

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Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT and Google Gemini to assist with phrasing text and identifying sources and historical information. Writefull was used for grammar and spelling check. After using these tools and services the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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