Exploring Archaeological Object Records Using the ARCH-ON Ontology

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Abstract

This paper presents initial results of developing ARCH-ON-Sampo, a demonstrator application for exploring and visualizing archaological cultural heritage. The application is based on a novel ontology-based classification scheme for archaeological artefacts. The ARCH-ON projects develops an attribute-based classification system for archaeological object data that will facilitate large-scale, including transnational, data harmonization and enable new computational approaches to studying material culture from the past.

Keywords

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

1. Introduction

A major challenge in the international Digital Cultural Heritage (DCH) landscape is the difficulty in bringing together for computational work large legacy artefact inventories 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.

The idea of organizing knowledge comes originally from Aristotle's (384–322 BC) ten categories. Peter of Spain (fl. 13th century) extended the idea to hierarchical subcategories based on differentiating features. After Carl Linnaeus (AD 1707–1778) developed his taxonomies for biology, the idea of Knowledge Organization Systems (KOS[2][2, 3]) has been applied in classification systems and typologies in libraries, museums, archives, and other fields. Drawing on this long tradition, archaeology has relied on classifying artefacts into *typologies* based on their form and other physical features [4]. 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 [5, 6, 7], which we group into two broad categories for the purposes of this discussion.

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[1]ARCH-ON project homepage: https://seco.cs.aalto.fi/projects/arch-on/
[2]Encyclopedia of Knowledge Organization: https://www.isko.org/cyclo/kos

From a humanistic research perspective, any application of typology-based 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 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. From the perspective of semantic research, therefore, classifications produced in the context of modern nation-states can be suboptimal for large-scale transnational data harmonization [8]. Moreover, the currently prevailing KOS for archaeological objects is not optimized to exploit the paradigm shift that occurred when "ontologies" [9] 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 initial concept of ARCH-ON and its ontology design is presented 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 application to help solving humanities research questions are also discussed.

ARCH-ON-Sampo is partially based on our previous work on FindSampo[3] and CoinSampo[4] [10]. Other international projects with related focus include the ARIADNEplus [11] project and its Ariadne portal[5] that harmonises European archaeological records, and the Nomisma ontology [12] for describing numismatic objects, and the various portals[6] that utilise it.

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 contrasts 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 [13]. This approach for modelling information on individual observations has been successfully tested on other fields of scientific inquiry, such as representing ecological information based on traits of insects [14].

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[7] [15]. Another important initiative has been the development of a CIDOC-CRM -based data model for archaeological fieldwork[8]. Toby Martin's successful test of a networked approach to investigating variations and relationships among early medieval European square-headed brooches – developed by dissecting the object to their constituent parts or "components" – has likewise prepared the theoretic and

[3] https://dev.loytosampo.fi/en/
[4] https://coinsampo.ldf.fi
[5] https://portal.ariadne-infrastructure.eu/
[6] See for example the Online Coins of the Roman Empire (OCRE) portal at: https://numismatics.org/ocre/.
[7] Nomisma initiative: https://nomisma.org
[8] See, e,g. https://cidoc-crm.org/crmarchaeo/, also applied in http://openarchaeo.huma-num.fr

methodological ground [7]. Our project continues this work on archaeological semantic modelling by extending it to the description of artefacts in general using a formal data model built on LOD principles.

The ARCH-ON data model is presented in greater detail in [1], using modelling medieval ampullae (pilgrim flasks or souvenirs, Figure 1) 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 metadata, dates assigned to the object, recovery location), and design elements and interpretative characteristics (e.g., religious motifs and their meanings). The underlying data model re-uses the CIDOC CRM ontology, the Dublin Core metadata terms[9], and the FOAF vocabulary[10]. 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.

Figure 1: A late medieval ampulla (pilgrim flask) (PAS record ID GLO-CAD658) with a crown motif on one side and a quatrefoil flower on the other. The object was recover near Bristol in South Gloucestershire. Image credit: The British Museum's Portable Antiquities Scheme.

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 both 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 [16]. Ampullae are small, typically leaden containers used by pilgrims to transport holy liquids, such as water and oils, from holy sites. Not only were these liquids found to cure and protect, but the vessels themselves might be prized as secondary relics [17]. Although ampullae were used throughout the medieval period, those dating between about 1350 and 1550 are of a particular type (studied here) in the form of 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 pinned to be clothing for display, but also (potentially) for display about the home. That said, many found through metal-detecting on arable farmland are found broken, presumably to release their liquids, perhaps as part of ritual activity in the medieval landscape [18, 19]. 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 [20, 21]. Most, about half (albeit not the example shown here), have a shell motif, itself an emblem associated with pilgrimage, specifically to the Spanish cult centre associated with St James the Great at Santiago de Compostela. Otherwise, these designs vary, and can include crowns,

[9]DCMI Metadata Terms: https://www.dublincore.org/specifications/dublin-core/dcmi-terms/
[10]FOAF Vocabulary Specification: http://xmlns.com/foaf/spec/

flowers, hearts, letters, etc. These devices may be completely random or personal choices of their makers, but more likely, they reflect an association with a particular shrine, and this has been explored by archaeologists such as Brian Spencer [22, 20, 23] and Michael Lewis [16]. Importantly in the context of the ARCH-ON project, however, these links are hard to investigate through just a physical study of the object and necessitate computer-aided programming to better understand relationships between objects and places, and interpret possible associations.

3. Demonstrator

As a proof of concept, 480 ampullae in the Portable Antiquity Scheme in England and Wales (PAS)[11] database of the British Museum 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 2026 on a SPARQL endpoint hosted at the Linked Data Finland platform [24].

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 very clear and generally agreed concepts with existing vocabularies such as the counties of England to represent find locations. Some vocabularies were derived from existing archaeological classifications, such as the Spencer [20] types for classifying the shell designs on ampullae, which also impact their shape. However, some vocabularies were created based on the data and its requirements. For example, a vocabulary of motifs was created solely for the case study, and includes only concepts that were required for this case study.

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. For this case study the most complex vocabulary is clearly the vocabulary of visual elements required to represent the motifs in the ampullae with 67 unique concepts.

Class	Num.	Explanation
archon:Completeness	6	Completeness of overall shape.
archon:Spencer_type	2	Brian 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	Motif

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, a web application[12] was created on top of the SPARQL endpoint using the Sampo-UI framework [25, 26]. The application supports faceted search [27] 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 answering humanities research questions. Because the application is created to use the ARCH-ON ontology, it is in principle easy to convert to other data that is modelled using the ontology. However, its features are designed for this specific use case in mind. For example, Spencer type is clearly only relevant for data dealing with medieval ampullae.

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 certain property path starting from instance of `archon:Archaeological_object`, with

[11] PAS: https://finds.org.uk
[12] 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 will be opened online later in 2026.

possible other restrictions when required. The facets then represent a certain 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.

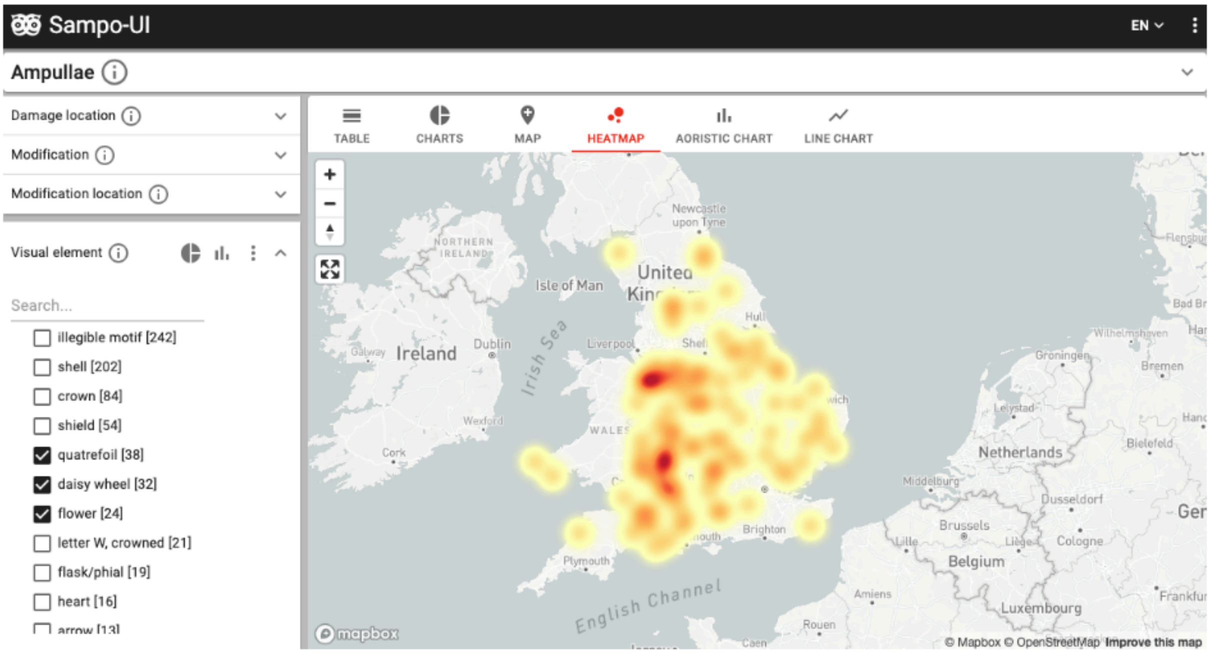

Figure 2: Screenshot of an ARCH-ON demonstrator showing the distribution of selected ampullae with floral motifs as a kernel density surface 'heat map'

Figure 2 shows a screenshot of the demonstrator. Here, ampullae can be examined using the facets on the left pertaining to the location where they were recovered and 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 heat map showing the distribution of ampullae filtered by using visual characteristics and other aspects that can inform on religious culture. Here the Heatmap tool has been set to display the distribution of ampullae with floral motifs (see Figure 1, and below). This visualisation method is based on Kernel Density Estimation. This technique is popular in various geospatial analyses to create a continuos smooth surface from a point pattern such as coordinate location in order to simplify and summarize the broader contours of its structure [28].

The hit counts in facets can also be used to give insight to the date. For example, in figure 2 it is easy to see from the facet hit counts that are ordered in descending order that, as discussed above, shell is the most common motif with over 200 ampullae. On the other hand, in even more cases the motif is unintelligible and cannot be determined.

4. Using the demonstrator

The use of Geographic Information System (GIS) software and other programming tools has provided an important avenue for archaeological research since at least the 1990s, particularly in dealing with large, complex datasets (e.g., [29]). These tools, however, require specialist training that is far from being mastered across the profession, much less among non-professionals who might also have needs and interests in accessing and studying DCH. The ARCH-ON data model and faceted data service is designed to democratize and empower rapid exploration of archaeological records by anyone, without training requirements [30]. The following use cases are presented as general examples of how the data on ampullae motifs and other attributes could be studied for generating 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 unknow local and regional cult centres and shrines. A simple examples is the motif “letter H”. The count in the visual element facet shows that it occurs on only four times in the dataset, suggesting that it is an unusual but not unique sign; the assistive visual element shows that the letter is always paired with the shell design on the other side. The Charts tool indicates that the shell design is always of Spencer type 2, which can be quickly visually verified in the Table view. The map tool locates all four ampullae in a relatively tight regional cluster in the county of Lincolnshire in eastern England. 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 inside or near the distribution area (see also [16]). Armed with this information a researcher interested in local religious practice could turn to further sources of evidence, such as investigating the closer archaeological landscape contexts of the finds, or studying which saints local medieval churches were dedicated to. Perhaps significantly, there are 17 medieval churches dedicated to St Helen in Lincolnshire, making her one of the more popular local saints surpassed only by the likes of Virgin Mary and the evangelists Paul and Peter.

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 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 internationally used as a visual reference to pilgrimage. The floral motifs are rarer, but still internationally encountered (e.g., in Denmark: [17]). The two design motifs usually fill one side of the ampulla in a manner similar to the obserse or “portrait/effigy" side of a coin. As such they were recognized so representationally important that Anderson made them two of the planks of his typology [18]. In England, finds with both motifs are encountered all over the country a manner that at first glance seems completely interspersed. The facility to select and compare main trends in the two geographical distribution patterns using the Heatmap tool, however, quickly reveals a clear geographic division, where the weight of the shell motif ampullae distribution lies in the east and that of the floral motifs in the west (Figure 2). This pattern could be reflective of regional trends in religious symbolic representation during the Middle Ages, perhaps connected to regional saints cults or influential religious foundations.

Relatedly, the Line Chart tool visualizing the spread of ampullae measurements shows that while the “length” and “width” dimensions of the two ampullae groups (for complete objects) do not substantially vary, the shell motif ampullae are considerably heavier in average (mean weight 41.24 g, median weight 41.00) than floral motif ampullae (mean weight 51.19 g, median weight 49.52 g). This likely indicates different material or manufacturing traditions. Ampullae (like almost all PAS finds that do not legally qualify as Treasure and are subsequently acquired by museums) are typically only visually assessed for their material of make, 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 [31]. Given that lead is *c.* 50 percent heavier than tin and was considerably cheaper, the considerably diverging measurement sets suggest novel information on different material and manufacturing traditions in eastern versus western England.

Moreover, it may be notable that ampullae linked to the shrine of Our Lady of Walsingham, Norfolk, are notably lighter again (mean weight 38.34 g, median weight 35.00). Walsingham was the second most important pilgrimage destination in medieval England only after Canterbury, and unusually for English cult centres we are able to confidently identify several motifs exclusively associated with the shrine (the “arrow”, “flask/vial” and “letter R, with staff” motifs, n=19 complete ampullae [18, 19, 16]). The relative lightness of the Walsingham ampullae could be due to a preference for the more expensive tin – which has a more silvery and therefore luxurious appearance – for aesthetic reasons 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 [31, 23, 21].

5. 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. The observations discussed above could in turn be linked to important patterns and processes regarding regional economic development, presence of mining industries and trade networks, or even commercialisation and the professionalization of crafts workshops. Future archaeological work is needed to test and verify them, but our example showcases data exploratory applications that are more fine-grained than those allowed by the standard typological KOS for material culture. They can used, as a first step, to identify potential groups of objects for later (and much more labour and resources intensive) scientific material analysis (e.g, pXRF). Being able to draw out observations such as these from large scale record data, one that has previously been regarded as quixotic and difficult to handle, will empower future researchers in pursuing better understandings of the material grammar of religious visual representation during the Middle Ages.

One promising avenue of further research is to consider international datasets. During the ARCH-ON project, openwork animal brooches of 10th-12th century date were identified as particularly promising. Produced in the North Sea region, from northern France to England and Denmark, they are frequently found by hobby detectorists and often registered thanks to the existence of national finds recording schemes in several countries. The transnational distribution has contributed to a disjointed understanding of these items, which have been separated in numerous types. While these existing classifications are in no way spurious, they tend to obscure the features that these objects share, to varying degrees. These include openwork designs; animal depictions of various types – often winged – in profile and frequently placed within a round frame; the ambiguity of certain iconographic features; and the greater or lesser affinity with Late Viking art styles. While some objects within this great spectrum of designs are evidently the output of larger-scale productions (including, most notably, some types of Urnes-style brooches [32]), others are quite unique or take up a hybrid position between established "types".

Item groups such as these are ideally suited for our approach: apart from the need to harmonize vocabularies based in national recording schemes, they are relatively narrow in scope and thus amenable to coherent description, yet with a diversity that is hard to capture through formal classification. The diverse dimensions of similarity and difference lend themselves well for a relational research approach [7, 33]. This opens up potential for new insights into the past. In the case of the openwork animal brooches, new information could be produced on the technical and iconographic inspirations shared by craftspeople across the North Sea region at this time, or the visual language of dress and how it interacted with other displays of identity. The same applies (albeit more specifically for religious visual representation) to the ampullae recovered across Europe, and to many other object types. Importantly, our approach can serve as a methodological tool, for instance in rethinking the extrapolation of chronological evidence in typological systems, or in redefining how individual artefacts constitute archaeological types. It can help to test and refine existing typologies and related archaeological KOS, advancing the development of the discipline's overall knowledge infrastructure.

A potential limiting factor for using an ontology like ARCH-ON is that it requires work and both subject matter expertise and understanding of ontologies. For example, in our example case creating a vocabulary of visual elements for the ampullae required making judgements on what constitutes a proper visual element. It can also be often difficult to determine the exact visual element of artefacts that may not be perfectly preserved. Modelling the resulting uncertainty is an interesting question, but requires even more work and a more complex model.

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