Towards a Realism-Based Ontology of Archeology: Artifacts, CIDOC-CRM and BFO

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Abstract

Archeology faces a critical issue of how to structure and reuse a rapidly increasing amount of archeological data and information. Ontologies are expected to address this problem by serving as a common semantic basis for their effective management. This paper aims to take the initial steps towards an ontology of archeology that is underpinned by the methodological principle for ontology development which is called "(ontological) realism". For this purpose, we focus on artifacts in archeology and provide an ontological analysis of an artifact-relevant modular part of the CIDOC Conceptual Reference Model (CIDOC-CRM), based on the realism-based upper ontology Basic Formal Ontology (BFO). We also examine CIDOC-CRM's capacity to accommodate multifarious artifacts in archeology in light of some illustrative examples thereof and propose a realism-based ontological approach to archeological artifacts in general.

Keywords

archeology, ontological realism, artifact, CIDOC Conceptual Reference Model (CIDOC-CRM), Basic Formal Ontology (BFO)

1. Introduction

Archeological studies undergo dramatic methodological changes with the advent of information technology in the digital age [1]. At the same time, it is an acute problem to structure, repurpose and reuse a proliferating amount of digital data in archeology [2, 3]. Ontologies attract growing research interest in this context, as they are expected to meet such a significant challenge by ensuring the semantic interoperability among different heterogeneous information resources in archeology [3], or more generally, in the domain of cultural heritage [4]. As a matter of fact, an ontological approach to archeological data has been theoretically and practically explored, for example when it comes to formally representing archeological sites [5, 6] and archeological artifacts [7, 8] in information systems.

In this paper we put forward the idea that the development of ontologies of archeology can be potentially fostered with recourse to the methodological principle of ontology development which is called "(ontological) realism" or the "realist methodology" [9]. The "fundamental principle of ontological realism" is "to view ontologies as representations of the reality that is described by science" (ibid., p. 139, de-italicized for readability). The efficacy of ontological realism can be observed in the fact that this methodology is adopted by the upper ontology Basic Formal Ontology (BFO) [10, 11, 12] and BFO has been widely used in many domains such as biomedicine (notably in connection with the Open Biological and Biomedical Ontologies (OBO) Foundry [13, 14]) and intelligence analysis [15].

There are arguably several reasons for accepting ontological realism in the building of ontologies of archeology. For one thing, the full deployment of archeological ontologies will warrant grounding them in a solid theoretical basis [16]. There is effectively heightened awareness of the importance of a foundational analysis of archeological ontologies. For instance, the CIDOC Conceptual Reference

Proceedings of the Joint Ontology Workshops (JOWO) - Episode XI: The Sicilian Summer under the Etna, co-located with the 15th International Conference on Formal Ontology in Information Systems (FOIS 2025), September 8–9, 2025, Catania, Italy

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CEUR Workshop Proceedings ceur-ws.org ISSN 1613-0073

published 2026-03-02

CEUR-WS.org/Vol-4176/swodch-5.pdf

Model (CIDOC-CRM) is a standardly used ontology for representing information about cultural heritage [4, 17] and it has been utilized e.g., in historical research [18] and archeology [3, 24].

It has been nonetheless highlighted that the foundation of CIDOC-CRM requires strengthening from logical [19] and ontological [20] viewpoints, as well as extending [18] by means of upper ontologies such as the Descriptive Ontology for Linguistic and Cognitive Engineering [21, 22]. Relatedly, an ontology of artifacts in Islamic archeology has been developed in alignment with DOLCE [8]. As BFO has been recently approved as international standard ISO/IEC 21838-2, the realist methodology — as embraced paradigmatically by BFO — can be expected to contribute to solidifying a theoretical foundation of archeological ontologies.

For another, ontological realism may be helpful in facilitating the reusability of archeological data. According to Huggett [2], relevant questions to digital data reuse in archeology include: "What are the implications of the different epistemologies associated with data analytics applied to archaeological data?" and "What mechanisms need to be put in place to support appropriate reuse of archaeological data?" (ibid., p. 101). In reply to these two questions, we think that the reuse of archeological data can be severely hindered by "different epistemological frameworks" (ibid., p. 99) for data analytics and ontological realism has the potential to enhance their reusability because it can serve as a common semantic framework for integrating these "data epistemologies" (ibid.). Moreover, the realist methodology may also be an effective tool for developing an inter- and transdisciplinary framework for archeology [23], as ontologies can be useful to establish it [24], while emphasizing that the context of discovery — which determines how a set of objects may be interpreted archeologically — is fundamental to archeological practice and theorizing, and it underscores the importance of fields in archaeology [25].

More concretely, we will illustrate the potential utility of ontological realism for the development of ontologies of archeology with the example of artifacts, as they are of central importance in archeology. First of all, we provide an ontological analysis of an artifact-related modular part of CIDOC-CRM within BFO's realism-based ontological framework (Section 2). Next, we clarify the limited scope of the CIDOC-CRM notion of artifact in terms of some examples of artifacts in archeology and propose a realism-based ontological approach to archeological artifacts in general (Section 3). Then, we discuss our findings in relation with related work (Section 4). Finally, we conclude the paper with some brief remarks on future work (Section 5).

2. An ontological analysis of artifacts in CIDOC-CRM

2.1. Artifacts in the CIDOC Conceptual Reference Model (CIDOC-CRM)

We will begin by adumbrating an artifact-related modular part of CIDOC-CRM. As there is no such explicit class as *Artifact* in CIDOC-CRM, we will focus on the following three classes thereof: *E22 Human-Made Object*, *E24 Physical Human-Made Thing* and *E25 Human-Made Feature* (where each class in CIDOC-CRM is prefixed by a unique ID starting with "E"). Note that we will write terms for classes and particulars in italics and bold, respectively.

We will first introduce *E24 Physical Human-Made Thing* because it is a superclass of *E22 Human-Made Object* and *E25 Human-Made Feature*. This class is annotated with the following "scope note":

> This class comprises all persistent physical items of any size that are purposely created by human activity. This class comprises, besides others, human-made objects, such as a sword, and human-made features, such as rock art. [...]
>
> Instances of E24 Physical Human-Made Thing may be the result of modifying pre-existing physical things, preserving larger parts or most of the original matter and structure, which poses the question if they are new or even human-made, the respective interventions of production made on such original material should be obvious and sufficient to regard that the product has a new, distinct identity and intended function and is human-made.

[17, pp. 74-75]

Based on this explanation, we can think that the notion of *E24 physical human-made thing* would correspond approximately to the traditional view of artifact as something that is intentionally produced for some purpose (see e.g., [26]).

Next, *E22 Human-Made Object* is a subclass of *E24 Physical Human-Made Thing* and it is annotated with the following scope note:

> This class comprises all persistent physical objects of any size that are purposely created by human activity and have physical boundaries that separate them completely in an objective way from other objects.
>
> The class also includes all aggregates of objects made for functional purposes of whatever kind, independent of physical coherence, such as a set of chessmen.

[17, p. 74]

Listed examples of *E22 human-made objects* include the Rosetta Stone and the Portland Vase. We remark that not only objects but also aggregates of objects can be instances of *E22 Human-Made Object* (see Section 2.3 for details).

Finally, being another subclass of *E24 Physical Human-Made Thing*, *E25 Human-Made Feature* is annotated with the following scope note:

> This class comprises physical features that are purposely created by human activity, such as scratches, artificial caves, artificial water channels, etc. In particular, it includes the information encoding features on mechanical or digital carriers. [17, p. 75]

Listed examples of *E25 human-made features* include the Manchester Ship Canal and the carved letters on the Rosetta Stone. We emphasize that not only physical features but also "non-physical" entities (e.g., information) relating to these physical features can be instances of *E25 Human-Made Feature* (see Section 2.3 for details).

2.2. A general overview of Basic Formal Ontology (BFO)

We will explain selected categories from Basic Formal Ontology (BFO) [10, 11, 12], as a preliminary to providing a BFO-based analysis of artifacts in CIDOC-CRM in Section 2.3. Figure 1 represents BFO's *is_a* hierarchy under the ISO standard. BFO includes the top-level distinction between continuants (which persist through time) and occurrents (which unfold themselves in time).

In the category of continuant, independent continuants include material entities such as cells and people. They also include immaterial entities, such as sites and continuant fiat boundaries. A site in BFO is: "An immaterial entity in which objects such as molecules of air or organisms can be contained" [10, p. 184]. Examples include my nasal cavity and the hold of a ship. A continuant fiat boundary in BFO is: "An immaterial entity that is of zero, one, or two dimensions and does not include a spatial region as part" [10, p. 108, italics omitted] (see [28] for more thoughts). Examples include fiat surfaces (e.g., the surface of the earth) and fiat lines (e.g., the Greenwich meridian).

A generically dependent continuant is a continuant that depends (existentially) on one or other independent continuant and can "migrate" from one bearer to another through a process of copying. Intuitively speaking, it is a "copyable pattern". Examples include pdf files (which can be moved from one storage device to another) and novels (which can have multiple printed copies).

A specifically dependent continuant is a continuant that depends (existentially) on at least one independent continuant. Examples include qualities (e.g., my height) and realizable entities such as dispositions, functions and roles (see e.g., [29] for more thoughts on realizable entities in BFO).

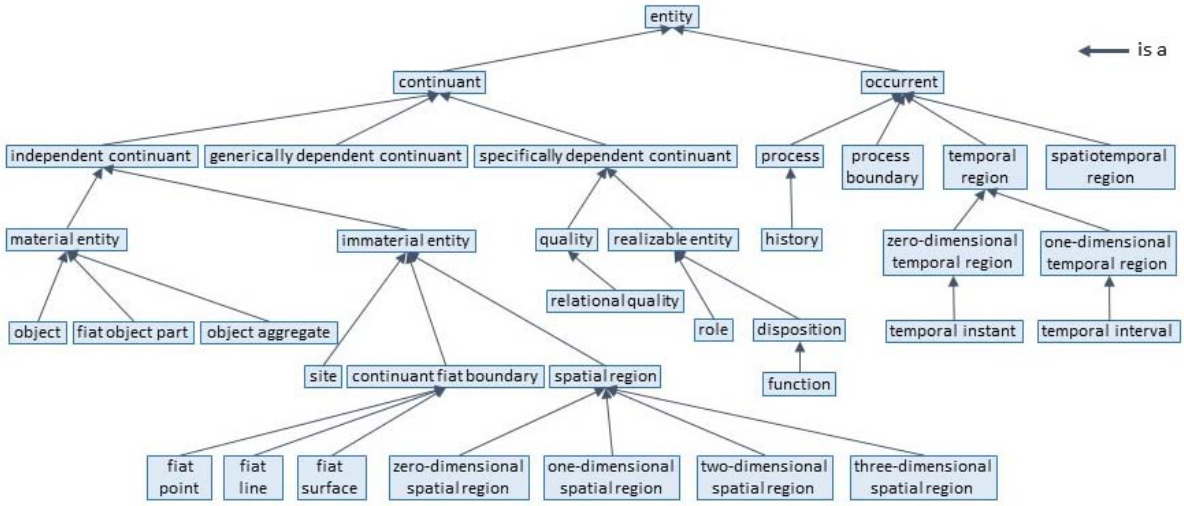

Figure 1: BFO's *is_a* hierarchy under the ISO standard (extracted from [27])

A disposition in BFO is a realizable entity that exists because of certain features of the physical makeup of the independent continuant that is its bearer. It is an "internally grounded realizable entity": if a BFO:disposition ceases to exist, then the physical makeup of the bearer is changed. Examples include the fragility of a glass and the flammability of a match.

A function in BFO is a BFO:disposition of a bearer with a specific kind of historical development [11]. It is a BFO:disposition that its bearer possesses in virtue of its having a certain physical makeup because of how it came into being, either through evolution (when the bearer is a natural biological entity) or intentional design (when the bearer is an artifact). Examples include the function of the heart to pump blood through the body and the function of a screwdriver to turn screws.

A role in BFO is a realizable entity that (1) exists because the bearer is in some special physical, social, or institutional set of circumstances in which the bearer does not have to be (optionality), and (2) is not such that, if this realizable entity ceases to exist, then the physical make-up of the bearer is thereby changed (external grounding). Briefly, a BFO:role is an externally grounded and optional realizable entity. Examples include the role of being a student and the role by a stone of marking a boundary.

In the category of occurrent, a process in an occurrent that exists in time by occurring, i.e., by having (proper) temporal parts, and which depends on at least one independent continuant as participant. Examples include a process of cell division and a process of my cutting meat with a knife.

2.3. A BFO-based analysis of artifacts in CIDOC-CRM

We will now analyze, from BFO's realism-based viewpoint, the three artifact-relevant classes in CIDOC-CRM, viz. *E24 Physical Human-Made Thing*, *E22 Human-Made Object* and *E25 Human-Made Feature*. First of all, in considering *E24 Physical Human-Made Thing* against the BFO ontological background, one might hypothesize that this class can be understood as a subclass of BFO:*Material entity* because *E24 physically human-made things* are "persistent physical items of any size", and BFO:material entities are spatially extended in three dimensions and continue to exist through some interval of time [10, p. 90]. One might also hypothesize that *E24 Physical Human-Made Thing* can be linked with BFO:*Function* because any E24 physically human-made thing has "a new, distinct identity and intended function and is human-made" and, when it is an artifact, the bearer of a BFO:function come into being — which would entail distinct identity — through intentional design [11].

These two hypotheses on *E24 Physical Human-Made Thing* are nonetheless arguably untenable when we closely examine its subclasses *E22 Human-Made Object* and E25 *Human-Made Feature.* Concerning the first hypothesis, it may certainly apply to *E22 Human-Made Object* because this class covers some

BFO:objects (e.g., the Rosetta Stone) and some BFO:object aggregates (e.g., a set of chessmen), and BFO:*Object* and BFO:*Object aggregate* are subclasses of BFO:*Material entity*.

As regards *E25 Human-Made Feature*, however, this class accommodates some BFO:sites (e.g., artificial caves) and some BFO:fiat surfaces (e.g., scratches), but BFO:*Site* and BFO:*Fiat surface* are subclasses of BFO:*Immaterial entity* — which is disjoint from BFO:*Material entity*. Moreover, *E25 Human-Made Feature* includes "information encoding [physical] features on mechanical or digital carriers" and such an informational entity can fall under BFO:*Generically dependent continuant* (disjoint from BFO:*Material entity*), or more specifically, under *Information content entity* — which is a subclass thereof in the BFO-compliant Information Artifact Ontology (IAO) [30].

Concerning the second, related hypothesis, it is important that the bearers of BFO:functions should be BFO:independent continuants that are not BFO:spatial regions. On the one hand, *E22 Human-Made Object* may be generally characterized in terms of bearing BFO:functions because all E22 human-made objects are BFO:material entities. On the other hand, E25 human-made features that are BFO:sites or BFO:fiat surfaces may be characterized in terms of bearing BFO:functions (but see [31] for the view that the current BFO specifications of dispositions and roles should be generalized to apply to e.g., sites), whereas those which are IAO:information content entities cannot be, because BFO:*Generically dependent continuant* is disjoint from BFO:*Independent continuant*.

All these discussions can show that the artifact-relevant classes in CIDOC-CRM are categorically heterogeneous with interpreted in the BFO ontological setting. In particular, *E24 Physical Human-Made Thing* includes not only some BFO:material entities but also some BFO:immaterial entities and even some BFO:generically dependent continuants. In our view, this is partly because the notion of being human-made is ontologically prior to the notion of being ontologically (in)dependent in CIDOC-ROM (which is tailored to meet the needs in cultural heritage), while the latter notion is rather ontologically prior to the former in BFO (which is a domain-neutral ontology that is predicated on ontological realism).

3. Towards a realism-based ontology of archeological artifacts

We will investigate the utility of the CIDOC-CRM notion of artifact in the domain of archeology by scrutinizing the aforementioned artifact-related classes in this ontology in light of some examples of artifacts in archeology that are extracted from the publication [32].[1]

On the one hand, some archeological artifacts can be understood in terms of *E24 Physical Human-Made Thing* and its subclasses. To illustrate this point, consider a blade (**blade$_1$**) out of flint stone in Figure 2 (see [32, pp. 94-103] for details). Then **blade$_1$** can be seen as an instance of *E22 Human-Made Object*, as it is an BFO:object that is intentionally produced to cut something. For that matter, we can think that **blade$_1$** has a BFO:function to cut. For another example, the Etruscan Necropolis of Cerveteri and Tarquinia may be considered as an instance of *E25 Human-Made Feature*, as it would be classied as a BFO:site that is intentionally produced to bury dead people. In effect, we may think that the Etruscan Necropolis has a BFO:function to bury dead people.

On the other hand, some archeological artifacts may be difficult to classify according to the artifact-relevant classes in CIDOC-CRM. For instance, consider an aggregate of approximately 500 small objects in Figure 3 (see [32, pp. 348-351] for details). They were discovered in the same archeological site, near the entrance of the Roman forum of Aventicum, Switzerland in 2003, and they vary greatly in size, material and color. According to one archeological interpretation, this aggregate of small objects (**object aggregate$_2$**) were deposited or abandoned, intentionally by different people, in order to bring luck.

It may be unclear whether **object aggregate$_2$** is an instance of *E22 Human-Made Object* or not, even though it may be an BFO:object aggregate. For one thing, it may not be intuitive to say that **object**

[1]The publication [32] was issued on the occasion of the exhibition *Des choses* at the Laténium, located in Neuchâtel, Switzerland, held from May 28, 2021, to January 9, 2022. This exhibition focused on unique objects that remain underexplored within the traditional research framework for understanding archeological objects.

Figure 2: A blade out of flint stone. Part of the collection of Laténium. Image reproduced with permission.

Figure 3: An aggregate of approximately 500 small objects, discovered in Aventicum, Switzerland in 2003. Part of the collection of Aventicum. Image reproduced with permission.

aggregate$_2$ is "human-made" through the intentional act of depositing or abandoning them (which would not involve substantial physical modification) and it had an "intended function" to bring luck. For another, **object aggregate$_2$** could have no BFO:function to bring luck, as BFO:*Function* is a subclass of BFO:*Disposition* — which exists because of certain features of the physical makeup of the bearer —– but, given (our knowledge of) the laws of nature of our actual world, there can be no physical entity to bring luck (see [33, 34, 35] for related thoughts on artifactual functions).

To borrow another example, a fragment of Roman terracotta slab in Figure 4 was discovered in

Figure 4: A fragment of a Roman terracotta slab containing a child's footprint, discovered in Avenches, Switzerland. Part of the collection of Aventicum. Image reproduced with permission.

Avenches, Switzerland and it contains a child's footprint (**footprint$_3$**) (see [32, pp. 374-377] for details). In general, footprints are of archeological value because they help to explore the culture and lifestyle at that time: for instance, the itineraries of people from that time and whether they used to walk barefoot or wear shoes. In our case, **footprint$_3$** attests to the presence of children at what were likely accessible production sites, such as terracotta workshops during the Roman period. Even if it could be construed as a BFO:fiat surface, **footprint$_3$** would not be an instance of *E25 Human-Made Feature*, as it was accidentally (and hence not purposely) left on the surface of the clay slab — which is a BFO:material entity that was intentionally produced, e.g., to cover the floor of a building. Moreover, it would be implausible to identify any BFO:functions of **footprint$_3$**.

These case studies can prompt the need for an alternative approach to artifacts in archeology beyond CIDOC-CRM. We propose that a realism-based account of archeological artifacts can be a promising candidate for such an approach. To outline this proposal, we will provide a brief BFO-based analysis of the two problematic examples of archeological artifacts, i.e., **object aggregate$_2$** and **footprint$_3$**.

Regarding **object aggregate$_2$**, it can be interpreted as a "faith-based artifact" by Koslicki & Massin [34]: roughly, an artifact of a kind that is intended and believed by its creators and users to perform a function (e.g., to bring luck) which it in fact does not perform. They also suggest that faith-based artifacts can be analyzed in terms of their notion of "placebo capacity": roughly, a capacity to subjectively satisfy an agent's desire to produce the relevant effect (e.g., to get lucky) in the presence of a belief by the agent that the entity is able to bring about this effect (e.g., to bring luck). For instance, amulets can be ascribed the placebo capacities to subjectively satisfy the user's desire to dispel evil spirits in the presence of the relevant belief on the part of the agent that they can in fact dispel evil spirits. Since amulets in fact lack the capacity to dispel evil spirits, however, the user's desire to dispel evil spirits is only subjectively, but not objectively, satisfied. As placebo capacities can be understood as BFO:roles (as distinct from BFO:dispositions, including BFO:functions) [33, 35], we can analyze **object aggregate$_2$** as an BFO:object aggregate that bore a placebo capacity (which is a BFO:role) to bring luck.

Regarding **footprint$_3$**, by contrast, its ontological analysis would be more difficult owing to the fact that unlike the clay slab, which had been intentionally produced, **footprint$_3$** was likely made accidentally on its surface at a later time — a phenomenon currently under investigation. Here it may be useful to consult Almeida & Costa's [8] DOLCE-based ontology of Islamic artifacts. They provide a

role-based approach to archeological artifacts as follows:

> From an ontological point of view, these categories ["some basic concepts in archaeology, such as those of artefact and ecofact"] of archaeological data are roles assumed by material objects. [...] No object is necessarily an archaeological artefact, only becoming one under certain conditions and for a certain period of its existence, e.g., after being recognised as an evidence of material culture in an archaeological site. [8, pp. 296-297]

This idea can motivate us to think, along with BFO, that **footprint$_3$** is an archeological artifact in virtue of bearing a BFO:role (**role$_3$**) to serve as "an evidence of material culture in an archaeological site". One apparent problem with this interpretation is the unclarity of the ontological nature of **role$_3$**.

Although tackling this issue fully exceeds the scope of this paper, we can offer some remarks as a pointer to further inquiry. According to Toyoshima et al. [33, 36, 35], the term "artifact" can refer to at least two related, but different kinds of entities: "canonical artifacts" and and "usefacts". A canonical artifact is something that is intentionally produced for some purpose (e.g., **blade$_1$** and clay slabs). A usefact is something that is intended to be used for some accidental purpose, i.e., for some purpose that is different from the purpose (if any) for which the entity was intentionally produced. For instance, when a pebble is intended be used to keep papers in place (even without being actually used in that way), this pebble is a usefact because it was not intentionally produced (since it is a natural object) and it is intended to be used for some purpose. We may think that **footprint$_3$** is a usefact, as it was not intentionally produced and it is intended to be used by contemporary archaeologists as an evidence of material culture, and that **role$_3$** can be analyzed as a BFO:role that exists in virtue of the archaeologists' interests in the circumstances in which the clay slab and **footprint$_3$** on it came to take shape during the Roman period (see [33, 36, 35] for details).

4. Discussion

We dedicate part of this study to examining the application of CIDOC-CRM in archaeological contexts. CIDOC-CRM plays a crucial role in the cultural heritage domain, as many widely adopted metadata schemas and standards there have been mapped to entities within this ontology [37]. Moreover, previous studies have explored the mapping of CIDOC-CRM to other metadata schemas or conceptual models — particularly in archeology [38] — and the potential benefits of applying machine learning techniques to CIDOC-CRM [39].

Unlike these existing works, we analyzed CIDOC-CRM by delving into subclasses of *E77 Persistent Item* that are relevant to archaeological artifacts within the framework of the BFO upper ontology. From a foundational perspective, CIDOC-CRM is widely recognized as "event-centric", with the representation of events (as illustrated by *E2 Temporal Entity*) being central to its scope (see e.g., [4] for more details). While *E2 Temporal Entity* — which constitutes the core dichotomy of this ontology alongside *E77 Persistent Item* — falls outside the purview of our investigation, a comprehensive study of relevant subclasses of *E2 Temporal Entity* and relations will require first strengthening the conceptual and logical bases for CIDOC-CRM (see e.g., [19, 20] for pointers).

One example of this line of future inquiry is to focus on *E11 Modification*, a subclass of *E2 Temporal Entity*, as well as on the relation *P31 has modified*, whose domain is *E11 Modification* — given its intimate connection with *E24 Physical Human-Made Thing*, which we investigated above: "[*E11 Modification*] comprises instances of *E7 Activity* that are undertaken to create, alter or change instances of *E24 Physical Human-Made Thing*" [17, p. 66, with italicization for readability].

5. Conclusion

The goal of this paper was to undertake a project to develop an ontology of archeology that is theoretically anchored to the methodological principle of ontological realism. To achieve this aim, we focused

on artifacts in archeology and provided an ontological analysis of an artifact-relevant modular part of CIDOC-CRM, in compliance with the realism-based BFO upper ontology. We also argued that the artifact-related classes in CIDOC-CRM (to wit, *E24 Physical Human-Made Thing* and its subclasses) may have difficulty with accommodating a wide variety of artifacts in archeology. Finally, we proposed and outlined a realism-based ontological approach to archeological artifacts in general, followed by a brief discussion in relation to related work.

There are several directions of research in which to further advance the project under consideration. One important task is, for instance, to synthesize and generalize the instance-level investigation into archeological artifacts (as conducted in Section 3) up to the class-level. A crucial step in addressing this task will be to develop a systematic account of artifacts and relevant realizable entities [33, 36, 35] as well as of realizable entities in BFO (e.g., [29]), as $\mathbf{blade_1}$ is inextricably linked with BFO:*Function* and, by contrast, $\mathbf{object\ aggregate_2}$ and $\mathbf{footprint_3}$ are with BFO:*Role*. Moreover, to fully assess the scope and validity of this proposal, it will be necessary to examine further examples of archaeological artifacts, such as those discussed in the publication [32].

Acknowledgments

This work is part of the project "An Ontology of Production, Products, and By-Products" (2023-2027; grant number #212493) funded by the Swiss National Science Foundation (SNSF). FT is financially supported by SNSF. FT's participation in the relevant workshop is made possible by funding from the Swiss Academy of Humanities and Social Sciences (SAHSS). The research has also been conducted in cooperation with the Swiss Center for Ontological Research (SCOR).

Declaration on Generative AI

During the preparation of this work, the authors used ChatGPT in order to: Grammar and spelling check, Paraphrase and reword. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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