# Ontoceramic: an OWL ontology for ceramics classification

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**Abstract.** In this note, we describe Ontoceramic, an OWL 2 ontology for cataloguing and classifying ancient ceramics. Ontoceramic has been defined through a synergic effort of computer scientists and archaeologists, by taking into account the most important papers in the field. It has been designed with the purpose of efficiently addressing significant problems concerning knowledge management about ceramics such as, for instance, classification by shape and type, and analysis of findings by their components. Ontoceramic implements CIDOC CRM, the standard ontology for describing concepts and relationships used in cultural heritage documentation, and LinkedGeoData for describing locations.

## 1 Introduction

In the last decades, the task of efficiently organize the classification process of archaeological findings – with particular focus on ceramics – has become more and more relevant for scholars and researchers in the field [10]. Currently, in fact, archaeological findings cataloguing and classification are often performed either by traditional methods, like hard-copy archives, or by standard digital techniques, like relational databases. However, such methods have severe drawbacks. For instance, they are often based on tools mainly developed and maintained locally; hence, they usually store partial data, rarely shared with the whole scientific community. This results in an incoherent use of information. Also, they do not support flexible data-management and information retrieval algorithms due to the lack of advanced reasoning means such as logical inferencing, consistency and soundness check.
*Semantic web* is a vision of the World Wide Web in which information carries an explicit meaning, so it can be automatically processed and integrated by machines, and data can be accessed and modified at a global level, resulting in increased coherence and dissemination of knowledge. Moreover, by means of automated reasoning procedures, it is possible to extract implicit information present in data, thus permitting to gain a deeper knowledge of the domain. Informally, in the context of computer science, an *ontology* defines a set of representational primitives (classes and attributes) with which to model a domain of knowledge or discourse

[11]. In the last years, the potential of ontologies has been recognized by archaeologists [1, 9]. Some projects have been undertaken concerning either single typologies of archaeological findings or several different materials related to each other [4, 7].
In this contribution we describe Ontoceramic [12, 3], an *OWL 2* (Ontology Web Language 2) defined by a synergic effort between computer scientists and archaeologists as a first step to overcome the problem of efficiently mechanize the task of correctly cataloguing ceramics and to make such knowledge easily retrievable by scholars and researchers in the field.
This initial definition of the ontology takes into account the most important papers in the field [4] and strongly relies on ICCD (Istituto Centrale per il Catalogo e la Documentazione) data sheets. The latter choice is motivated by the need of easily importing data from relational databases currently used in archaeological institutions (i.e., universities, museums, superintendences of cultural heritage). Moreover, ontoceramic implements the ontology CIDOC CRM [9] that provides a formal structure and definitions for describing concepts and relationships used in cultural heritage documentation, and furnishes the "semantic glue" needed to integrate different sources of information, such as the ones published by museums, libraries, and archives. Ontoceramic also implements LinkedGeoData [13], a large ontology for spatial knowledge base. It consists of more than 90 classes, 33 object properties, and 20 data properties. It includes a number of SWRL (Semantic Web Rule Language) rules[1] allowing several reasoning tasks on the knowledge domain in a short time.
The expressive power of the language underlying Ontoceramic has been studied in [12, 2]. In particular, in [12], we defined an *OWL 2* profile constructed from a decidable fragment of set theory and proved that the computational complexity of the consistency problem for Ontoceramic knowledge bases is NP-complete.
Ontoceramic has been developed using the *Protégé* editor[2] and classified by the Hermit,[3] Pellet,[4] and FaCT++[5] reasoners.

## 2 Ontoceramic

Ontoceramic aims at covering different aspects of the ceramic classification and cataloguing problem.
To begin with, Ontoceramic helps in identifying unambiguously the location of findings. One can have many locations to consider for a specific finding such as province, region, state, and so on. Locations are introduced by means of a taxonomy of OWL classes. Association between locations is performed by means of a taxonomy of object-properties. The

[1] http://www.w3.org/Submission/SWRL/
[2] http://protege.stanford.edu
[3] http://hermit-reasoner.com
[4] https://www.w3.org/2001/sw/wiki/Pellet
[5] http://owl.cs.manchester.ac.uk/tools/fact/

path allowed is shown in Fig. 2, where double-hoop entities are optional. Classes and object-properties involved are shown in Fig. 1. Reasoning tasks involving places are strengthened using SWRL rules of the type of the ones showed in Fig. 3. The entity "Localisation" is equivalent to "LinkedGeoData:Place"; equivalences between subclasses of "Localisation" and of "Place" are not reported here for space reasons. The object-property "hasLocalisation" is a subproperty of the CIDOC property "P54_has_current_permanent_location".

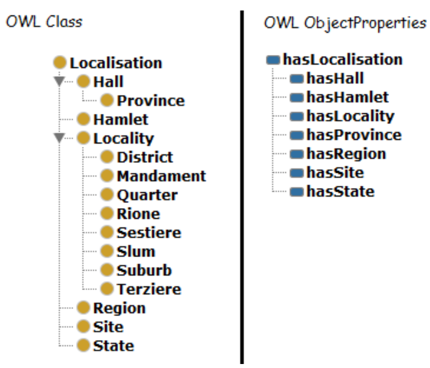


**Fig. 1.** Classes and properties for locations.

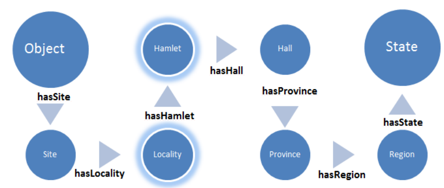


**Fig. 2.** Allowed path for locations.

| OntoCeramic Rules |
| --- |
| Locality(y), hasLocalisation(?x,?y) → hasLocality(?x,?y) |
| Region(y), hasLocalisation(?x,?y) → hasRegion(?x,?y) |
| State(y), hasLocalisation(?x,?y) → hasState(?x,?y) |
| Hamlet(y), hasLocalisation(?x,?y) → hasHamlet(?x,?y) |
| Hall(y), hasLocalisation(?x,?y) → hasHall(?x,?y) |
| Site(y), hasLocalisation(?x,?y) → hasSite(?x,?y) |
| Province(y), hasLocalisation(?x,?y) → hasProvince(?x,?y) |

**Fig. 3.** SWRL rules for reasoning with locations.

Ontoceramic is also able to handle components belonging to a specific object. For example, a cup can be found broken in three disjoint parts that may require distinct descriptions. Usually, in hard-copy versions of ceramic catalogues, components of a object are included in a descriptive field of the archive. Thus, information about each component can be extracted manually by the users or by means of search keys. In Ontoceramic, instead, objects as well as their fragments are considered as entities. Such classes are subclasses of the CIDOC "E22_Man-Made_Object". Each fragment is associated to the object it belongs to by the object-property "IsFragmentOf". Analogously, each object is associated to its components by the object-property "hasFragment" (notice that "hasFragment" and "IsFragmentOf" are inverses of each other) and, in particular, also by its sub-properties. Subproperties of "hasFragment" are intended to relate an object with one of its fragments, taking care of its correct functionality in the object. Thanks to this construction, one can precisely describe every part of an object. “isFragmentOf” is a sub-property of the CIDOC “P46_is_composed_of”. Types of fragments that can be implemented and also extended are described in Fig. 4. Object-properties which associate objects to their fragments are shown in the taxonomy illustrated in Fig. 5.

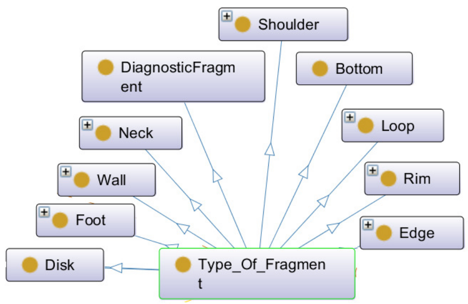


**Fig. 4.** Classes of fragments.

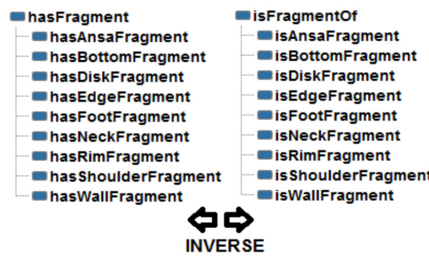


**Fig. 5.** Properties for fragments.

The class of an object is structured in a taxonomy as shown in Fig. 6. To assign a class to an object, the object-property “hasClass” is provided, having “Object” as domain and “Class” as range. The type of an object is represented in the “Object” taxonomy. “Class” is a subclass of CIDOC “E25_Man-Made_Feature”.
Sample and sector of a finding are represented by the classes “Sample” and “Sector”, respectively. Instances of these classes are associated to an object by means of the “hasSample” and “hasSector” object-properties. Ontoceramic can also specify the color of a finding using the Munsell Color System by means of the data-property “hasColor”. This property is endowed with three sub-data-properties, namely “hasChroma”, “hasHue”, and “hasValue”, for Munsell chroma, hue, and value, respectively. In addition, one can provide the discovery date and a general additional description of the object under consideration using, respectively, the “hasSiteDate” and “hasGeneralDescription” data-properties.
For objects and fragments one can specify their measurements. For example, thickness of an object can be represented by the generic data-property “hasThickness” and by its specific subproperties. For instance, the data-property “hasWallThickness” is used when we indicate the thickness of the object wall, “hasBottomThickness”, instead, is used when we indicate the thickness of the foot, and so on. The hierarchy of these properties is shown in Fig. 7.
It is possible to specify whether a fragment can be physically associated with another fragment to compose a unique object. In this case the “isFittedWith” object-property is applied. One can indicate the number of the box and the number of the sheet of the hard-copy archive of an object description using a “nonNegativeInteger” value in “hasBox” and “hasSheet” data-properties, respectively.

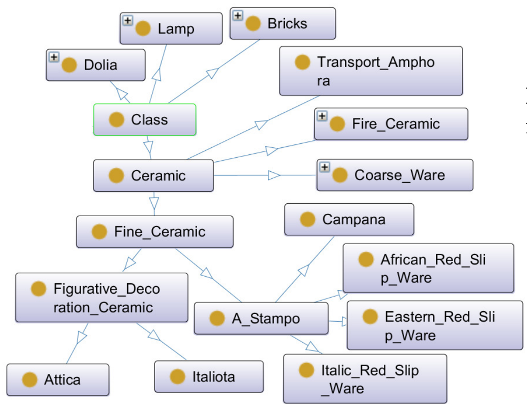


**Fig. 6.** Taxonomy of Classes.


**Fig. 7.** Data-Properties for measurement.

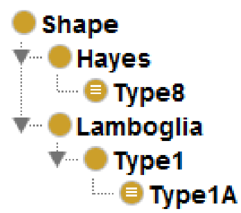


**Fig. 8.** Taxonomy for Shapes.

To solve a problem concerning the management of the shape of a finding, the "Shape" taxonomy is provided, as shown in Fig. 8. The shape of an object is represented by the "Shape" class. Instances of this class and of its subclasses are associated to an object by means of the "hasShape" object-property. Every instance of the class "Shape" can be uniquely identified by the properties "hasFirstShapeDescriptor", "hasSecondShapeDescriptor", "hasThirdShapeDescriptor", which are subproperties of the "hasShapeDescriptor" data-property. For each data-property, a string value can be specified: these values will be the keys for the "Shape" instances. These properties can be used as additional human-readable descriptors. At present, Ontoceramic supports only few types of "shape" and of "shape type", but one can add an arbitrary number of these classes and possibly assert equivalences among them. Currently, there is no world-wide agreement on the use of a specific nomenclature to indicate the shape and the type of an object. The "Shape" taxonomy is an attempt to face this problem providing a class for each type of shape and several classes for each specific shape; where required, an equivalence relation can be established among the shape classes or their sub-classes, to identify shapes which are identical with respect to the classification system but which have been called with different names. For example, in Fig. 8 "Lamboglia 1A" and "Hayes 8" are represented as equivalent. The class "Shape" is a subclass of CIDOC "E25_Man-Made_Feature".

## 3 Conclusions and future work

In this preliminary work we have presented an ontology which takes advantage of semantic web technologies in order to accomplish several tasks related to ancient ceramics cataloguing and classification such as reasoning on location, shape, and type of findings. We are currently populating Ontoceramic with datasets of ceramics coming from excavations located in eastern Sicily. We also plan to include support for stratigraphic excavations, bibliographic references management including authors and revisors, and identification of the production factory.

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