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Tong Wei

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THÈSE

Pour obtenir le grade de

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Présentée par

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Terminology and Ontology for Cultural Heritage: Application to Chinese Ceramic Vessels

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Abstract

Cultural heritage is the legacy of physical artefacts and intangible attributes of a group or society that is inherited from past generations. Vases are among the most iconic objects of cultural heritage. In the context of this work, we have focused on Chinese ceramic vessels of the Ming Dynasty (1368-1644) and the Qing dynasty (1644-1911). There are many collections of vases in different museums in China. Although some of these collections have been digitized, they are rarely accessible in an open format and remain isolated. In addition, the lack of clearly identified terminologies is an obstacle to communication and knowledge sharing.

Our work aims to respond to this issue by implementing practices drawn from the semantic web and knowledge engineering, and more particularly by building in a W3C format an ontology dedicated to the Chinese vases of the Ming and Qing dynasties.

The construction of the TAO CI ("ceramic" in Chinese) ontology respects the experts' way of thinking in their conceptualization of the field, and takes into account the international standards in Terminology (ISO 1087 and ISO 704). Both approaches are based on the notion of essential characteristics and define a concept as a unique combination of characteristics. The search for differences between objects, combined with a morphological analysis of Chinese terms whose characters carry meaning in relation to knowledge of the field, allows identifying essential characteristics. The definition of concept is based on the idea that a concept is a set of essential characteristics stable enough to be named in language. We have thus proposed a specific method for building ontologies guided by the terms and essential characteristics of the domain. We have introduced new terms (neologisms) in English and concepts without any designation in language for ontology structuring purposes. The definition of terms in natural language follows the Aristotelian definition. It is based on the formal definition of concepts denoted by the terms.

The construction of the ontology was done using Protégé, the most widely used environment for building ontologies in the W3C format (RDF/OWL). As the notion of essential characteristic does not exist in Description Logic, it was necessary to translate them. We have proposed some principles to this end. The terminological dimension was reduced, as is often the case, to annotations (in SKOS, RDFS) on the concepts. The TAO CI ontology is linked to external resources such as CIDOC CRM and ATT Getty for the conceptual part, and to museums for the objects. Finally, the TAO CI ontology was evaluated from the point of view of the domain (coverage) and its implementation. The ontology is in open access at the following address: <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl>

The last phase of the project consisted in the creation of a dedicated website. This site provides access to the different resources of the project and, in particular, to a bilingual (English, Chinese) electronic dictionary of the vases of the Ming and Qing dynasties. The dictionary entries correspond to the OWL classes of the ontology: <http://www.dh.ketrc.com/>

The TAO CI ontology is, to our knowledge, the first open and reusable ontology in the format of the semantic web of Chinese ceramic vases. It is an illustration of an approach guided by terms and essential characteristics that can be applied to the construction of ontologies in other areas of Chinese cultural heritage.

KEYWORDS: terminology, ontology, ontoterminology, cultural heritage, digital humanities, semantic web, linked open data, e-dictionary, Chinese ceramic vessels.

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PART I: INTRODUCTION

“路漫漫其修远兮，吾将上下而求索”

-----屈原《离骚》

Motivation

The motivation of this thesis is to publish open and linked data about the Chinese ceramic vessels of the Ming and Qing Dynasties, as well as the terms denoting them, using the standards of the Semantic Web. Since the beginning of the 2000s, Semantic Web technologies and their potential for the integration and exploitation of digital cultural heritage information have received increasing attention (Mantegari, 2010, p. 44). Research has already been done on how to link cultural heritage collections using ontologies (De Boer et al., 2012; Dijkshoorn et al., 2014; Doerr, 2003; Doerr et al., 2010; Dragoni, Cabrio, et al., 2016; Gwinn & Rinaldo, 2009; Kaufmann, 2006). This interest in the development of the Semantic Web of cultural heritage has inspired several large-scale international projects – amongst which are Europeana¹, CARARE², and ARIADNE³ (Wilcke et al., 2019). The vision of the Semantic Web proclaims a Web of machine-readable data that allows software agents to carry out relatively complex tasks for humans automatically. The semantic interoperability of Web resources is vital to realizing this vision. However, such interoperability is not the primary goal of heritage institutions that are looking for just another way of providing both academic and non-experts (e.g., pupils and lifelong learners) with access to their collections and related knowledge (Ross, 2003). This goal can be accomplished, for example, through online collections and exhibitions that not only display objects and simple descriptions (drawn from metadata) but also allow for understanding relationships between objects (created by semantically interrelated metadata) (Ross, 2003). In the Semantic Web architecture, semantic relationships are not embedded but explicitly represented by an ontology or an interrelated set of ontologies (Ross, 2003). Semantic Web technologies are instrumental in integrating these vibrant collections of metadata by defining ontologies that accommodate different representation schemata and inconsistent naming conventions over the various vocabularies (van Gendt et al., 2006; Wang et al., 2008). The central hypothesis underlying this work is that the use of explicit background knowledge in the form of ontologies/vocabularies/thesauri is, in particular, useful for information representation and retrieval in knowledge-rich domains (Schreiber et al., 2008). Therefore, the key to realizing this goal of heritage institutions is to build a suitable ontology.

China has a rich cultural heritage and has concentrated on producing “digital” data under the first wave of digitization. Most heritage institutions in China have not published cultural heritage data onto the Semantic Web because there is no ontology to offer the semantics of relevant data. Moreover, every institution accumulates its data in its traditional database system rather than linking data through an open data policy. As Daquino said, “the heritage institutions need to deal with two urgent issues for linking cultural heritage data: on the one hand, they need to provide a complete and exhaustive semantic description of their data; on the other hand, they have to open up their data to interchange, interconnection and enrichment ” (Daquino et al., 2017). These issues are also true of the knowledge domain of Chinese ceramic vessels. Chinese ceramic vessels are a wealthy domain, yet it lacks knowledge representation models (ontologies) to capture Chinese pottery concepts, express them in Semantic Web compatible interchange formats, and make them shareable and linkable to other data. Therefore, this work proposes the TAO CI (i.e., “Ceramic”) ontology

¹ See <https://www.europeana.eu/fr>

² See <https://www.carare.eu/>

³ See <https://ariadne-infrastructure.eu/>

to bridge this gap and solve these issues. In compliance with the ethos of reuse recommended by the W3C, the TAO CI ontology relates to existing ontologies and thesauri, such as CIDOC CRM (Doerr, 2003), EDM (Doerr et al., 2010), and AAT (Soergel, 1995).

First, As the initial ontology of Chinese ceramics vessels within our observations, this work intends to publish the resulting structured data onto the Semantic Web for anybody interested, including museums hosting collections of these vessels. Another aims to give a knowledge representation model (ontologies) to publish open data of Chinese ceramic vessels onto the Semantic Web for heritage institutions in China. As such, the TAO CI ontology intends to provide a significant reference to publish other cultural heritage ontologies and to be conducive to more and more Chinese heritage institutions publishing open cultural heritage data and linking them. Second, the theoretical and methodological adopted to build the TAO CI ontology are term-and-characteristic guidance, i.e., it assumes the ISO principles of Terminology (ISO 1087-1 and 704), which focus on the essential characteristics of defining concepts. Finally, this work tries to enrich existing methodologies of developing domain ontology by taking into account term-and-characteristic guidance, which makes ontology engineering less dependent on formal languages and description logics as the required background.

A further motivation for this thesis lies in the challenge of building knowledge-based terminological resources. The cultural heritage has the features of a region, national culture, and history. For experts or students with unique language backgrounds, it is difficult to understand the objects denoted by the terms only through the terms. Building terminology resources to meet this kind of requirement needs to base on knowledge infrastructure. Domain ontology is a better way to build a knowledge infrastructure. There are some works have been carried out, such as knowledge-based terminological e-dictionaries: EndoTerm (Carvalho et al., 2015) and al-Andalus pottery projects (Almeida et al., 2016), integrating and reusing terminological resources (León-Araúz et al., 2019), using open data to create the Catalan IATE e-dictionary (Vázquez et al., 2019), dictionaries for Greek material culture terms (Papadopoulou & Roche, 2018, 2019).

In the domain of Chinese ceramic, the heritage institutions adopt a descriptive approach to designating ceramics. For example, the Nanjing museum adopts the following order of modifiers for naming Tibetan ceramic (霍华, 1989): dynasty + kiln + glaze + colour + decoration + shape + texture + type. The information conveyed by the modifiers expresses knowledge of different nature, either essential, such as shape, material, and type, or descriptive, like glaze and color. For example, the term “清 雍正 粉青釉 凸花 如意耳 蒜头 瓷 瓶” (for convenience of non-Chinese speaker, we put spaces between modifiers) conveys the descriptive characteristics of dynasty (“清” Qing dynasty), emperor (“雍正” Yongzheng mark), glaze-color (“粉青釉” powder blue glaze), and decoration (“凸花” designed with flowers). It also conveys the essential characteristics of handle (“如意耳” Ru-Yi handle), shape (“蒜头” garlic-like head), material (“瓷” porcelain), and type (“瓶” vase). The English translation of the Chinese ceramic terms used by the Nanjing museum does not follow the Chinese order of modifiers, but the following order: glaze + colour + shape + texture + type + decoration + period + kiln. Thus, the previous term “清 雍正 粉青釉 凸花 如意耳 蒜头 瓷 瓶” is translated as: “powder blue glaze garlic porcelain vase designed with flowers and Ru-Yi handles, the Yongzheng mark of Qing dynasty”. Although this naming approach could reflect characteristics of ceramics, it is not conducive to communication with experts and students of archaeology. In practice communication, we often use the shape term, such as “蒜头瓶 (garlic-head vase)”. However, this kind of designation (shape

term of a vessel) often denotes over one concept or lacks terms of English, which usually leads to terminology ambiguity in communication. Therefore, we proposed new terms (neoterms) and gave their definitions in building terminology e-dictionary of Chinese ceramic vases.

Additionally, this terminology e-dictionary not only provides the terms but also displays the essential characteristics of objects denoted by terms, images of instances, and the definitions of these terms in natural languages. The main contribution of this thesis is the building the first ontology and terminology (ontoterminology) in the domain of Chinese ceramic vases.

Issues

Naming and defining things for linking open data

The W3C recommendation is linking open data using the RDF standard with the vision of having globally accessible linked data onto the internet, an open environment where distributed data can be created, connected, and consumed on the internet scale⁴ (Vandenbussche et al., 2017). Linked open data is structured information using formats processable by machines. The core task for publishing linked open data is, therefore, to publish data in machine-understandable interchange formats. The method of data formalization is ontologies, also called vocabularies of W3C terminology⁵. Naming things and defining things are two aspects of terminology work. The former refers to identifying terms of denoting the things (concepts), while the latter refers to identifying concepts denoted by terms. Names of things (terms) in the cultural heritage domain and their meaning (concepts) need to be expressed for Linking Open Data unambiguously. Challenges of naming things and defining things for the Semantic Web and integrating them in the Linked Open Data Cloud have led to ever closer ties between terminology and ontology engineering (Durán-Muñoz & Bautista-Zambrana, 2013; Roche, 2012a; Temmerman & Kerremans, 2003). When domain experts (archaeologists, historians, museum curators) have to express and share information about these collections, in this context, we are interested in how they define the terms denoting these objects, rather than the various meanings of these terms in texts. How to conceptualize and formally express the terms in the domain of cultural heritage has become a central issue in the efforts to expose and link open cultural heritage data onto the web.

Terminological issues

According to Andrews et al. 2012, an ontology describes concepts of the domain and relationships that hold between those concepts. While ontology occupies a central place in the structure of Semantic Web data, defining domain terms falls within the discipline of Terminology. "the science studying the structure, formation, development, usage, and management of terminologies is in various subject fields" (ISO 1087-1, 2019). Every terminology includes two dimensions: the linguistic dimension and conceptual dimension. Computational ontologies have been put forward as building blocks of knowledge-based multilingual

⁴ https://www.w3.org/egov/wiki/Linked_Open_Data

⁵ <https://www.w3.org/standards/semanticweb/ontology>

terminological resources, from healthcare and medical science to cultural heritage and the humanities (Carvalho et al., 2015; Roche et al., 2019). It is an interdisciplinary task to develop a multilingual terminological resource involving domain experts, terminologists/linguists, and knowledge engineers (Meyer et al., 1992). Defining terms written in natural language based on formal definitions/descriptions of classes is the critical challenge to terminology work and knowledge engineering, when researchers build a multilingual terminological knowledge base. So, it is necessary to distinguish language-specific aspects from the conceptual dimension of terminology work, which pertains to extra-linguistic domain knowledge (Santos & Costa, 2015).

Ontological issues

Building a domain ontology means use of formal languages and logic. It enables an ontology to implement computational models that store domain knowledge (real-world objects, events, relations) in the form of machine-understandable statements. Ontologies depend on description logics (DL) for their knowledge representation and W3C interchange formats for their formal representation. However, experts with domain knowledge are rarely proficient in model or ontology development and do not know the formal languages or logic that express ontological concepts (Westerinen & Tauber, 2017), which become an issue of building domain ontology for domain experts; namely, how to use formal languages for defining concepts in a user-friendly way, even to those who do not have a background in formal languages. As Westerinen notes, “asking a domain expert to use an ontology-authoring tool or to understand the complexities of a description logic language (such as OWL) may result in errors or omissions, or in the expert becoming frustrated and losing interest entirely” (Westerinen & Tauber, 2017 in Roche & Papadopoulou, 2019). A participant in interviews conducted by (Vigo et al., 2014) states the same problem, as viewed by knowledge engineers, “A domain expert has to be convinced that ontologies are the right way of modeling knowledge in a domain, and then has to consistently work for a period of time in order to be self-sufficient. In the initial stages, when they start doing the modeling, they need a knowledge engineer to hold their hand [...] the moment the knowledge engineer disappears, they will not carry on with it because it is much easier to get in databases or Excel than to do all this” (Vigo et al., 2014).

According to Uschold & Gruninger, 1996, “an [explicit] ontology may take a variety of forms, but necessarily it will include a vocabulary of terms and some specification of their meaning (i.e., Definitions).” The concept in our method follows the ISO principles of Terminology, where a concept is defined as a set of essential characteristics. For domain experts, identifying and defining concepts, identifying the essential characteristics, representing concepts, and essential characteristics for LOD are issues for building domain ontology. At present, the Semantic Web does not take enough advantage of the experience built up in knowledge engineering and conceptual modeling. To create the real Semantic Web, we have to develop and use well-founded generic ontologies based on linguistics and logic (Geser, 2003).

Cultural Heritage issues

In the domain of cultural heritage, the interoperability of heterogeneous resources on the Semantic Web is critical (Doerr, 2009). Tangible cultural heritage, comprising physical, cultural artifacts, immovable

architectural structures, and moveable objects, is a very diverse field. The information on cultural heritage objects, such as author, ruins, material, and period, could be distributed among different data resources. Owners of tangible cultural heritage data publish resources on the Web using different knowledge representation models (ontologies). This heterogeneity increases the difficulty of interoperability. Having a unifying knowledge representation model (ontologies) is necessary to publish interoperable cultural heritage data online (Hyvönen, 2012). Chinese ceramic vessels are a rich cultural heritage domain. Yet it lacks knowledge representation models (ontologies) to capture Chinese pottery concepts, express them in Semantic Web compatible formats, and make them shareable and linkable to other data. The TAO CI ontology aims and hopes to fill this gap.

Research questions

The principal research question of this thesis is as follows:

- * *What are the theoretical and methodological assumptions underlying the creation of an ontoterminology in the domain of Chinese ceramic vessels?*

More specifically, questions:

- * *How to create a domain ontology of Chinese ceramic vessels following the approach of ontoterminology?*
- * *How to take into account the way of thinking of humanists in building terminology and conceptualization?*
- * *How to build multilingual terminological resources based on the domain ontology for experts and students' communication in the domain of Chinese ceramic vessels?*
- * *Under the situation that domain experts did not know description logics and formal languages, how to implement ontoterminology on Protégé to build domain ontologies for domain experts?*
- * *Provide an ontology-oriented approach for digital preservation of cultural heritage.*

Objectives

The objectives of the TAO CI project are as follows:

- 1) Following previous work in the framework of ontoterminology, this thesis aims to build a bilingual (Chinese and English) terminological knowledge base (e-dictionary) of Chinese ceramic vases for archeologists and students.
- 2) Building an ontology to represent knowledge in the Chinese ceramic vases of Ming and Qing dynasties and publish these open linked data on the LOD.
- 3) Propose an approach for translating essential characteristics into Protégé.
- 4) Provide a reference for archaeologists, knowledge engineers, ontology engineers, and terminologists working on this domain.
- 5) Enrich existing methodologies of building domain ontology by means of a term-and-characteristic guided approach so as to reduce the dependence on logic and formal language.

Methodology

This thesis follows previous work within the framework of ontoterminology, whose definition is “a terminology whose conceptual system is a formal ontology” (Roche, 2012a). In our work, Terminology is considered as a discipline concerned with specialized knowledge and its linguistic expression. Terminology work includes two dimensions: the linguistic dimension and conceptual dimension (Roche, 2015). The linguistic dimension focuses on the term as a verbal expression of a concept in a specific natural language, while the conceptual dimension focuses on concepts denoted by terms, the relations between them, and the formal expression of concepts. An ontology is an “explicit specification of a conceptualization” (Gruber, 1993). Through the formal expression of conceptualization, ontoterminology unifies terminology and ontology into a single paradigm.

The method adopted in this thesis is term-and-characteristic guided derived from the work carried out in Digital Humanities (Roche & Papadopoulou, 2019), taking into account the following ISO principles of Terminology: “a term is a verbal designation of a concept” and “a concept is a unique combination of (essential) characteristics” (ISO 1087-1 and 704). An “essential characteristic” is a characteristic (abstraction of a property) of a concept that is indispensable to understand that concept (ISO 1087-1). Essential characteristics correspond to rigid predicates in DL (Guarino & Guizzardi, 2006) and the rigid properties of the OntoClean method (Guarino & Welty, 2004). The principal idea of the term-and-characteristic guided approach is that domain experts know their domain terms, and that a concept is a set of essential characteristics, which are stable enough to be named in a natural language by means of a term. Firstly, domain experts list the essential characteristics of concepts denoted by terms. Secondly, the terms guide domain experts to define the concepts denoted by terms. Although any combination of (essential) characteristics potentially defines a concept, not all of those combinations are meaningful for the domain experts. Terms can be thus considered as guiding the building of the ontology. Lastly, we need to translate the ontology in OWL or RDF by using tools and, then, evaluate the resulting ontology. Thus, the problem is centred upon identifying the essential characteristics for each concept. This is the central phase of our methodology. This phase is based on identifying differences between objects (vases with neck versus vases without neck), and on a morphological analysis of Chinese terms whose characters carry meaning concerning the denoted objects. For example, in the term "清德化窑白釉堆雕花卉瓷碗", the first character (清) represents the Qing dynasty, and the last one (碗, bowl) represents the type of vessel. The role of the terms in our work is to guide us to construct concepts and to provide the essential characteristics.

Let us note that our method does not include a “term extraction” phase, since the terms that denote vases are already known to the experts. The term-and-characteristic guided approach offers three critical advantages: the first one concerns the representation of knowledge: the resulting ontology is more ‘granular’. The second is that this approach allows to build a multilingual terminological knowledge base. The third is that the barrier of exposing data on the Semantic Web is lowered as ontology building using our proposed method assumes no background in formalizing using restrictions by the ontology engineer.

Thesis structure

The topic of this thesis is interdisciplinary. It combines the fields of Knowledge Representation, Cultural Heritage, Terminology, Ontology, Semantic Web, and Linked Data. The structure of this thesis is as follows.

Part I aims to introduce the readers to the motivation, issues, objectives, and methodology of this thesis.

Part II is the state of the art. It includes four chapters: Terminology, Ontology, Ontoterminology, and Semantic Web for Cultural Heritage. The terminology chapter introduces the definitions, theories, methods, languages, and tools of terminology. The ontology chapter presents the ontology definitions, theoretical foundations of ontologies, languages, methods, and tools. The ontoterminology chapter shows the previous work in the frame of ontoterminology, which consists of the definition, theory, method, and tools. Ontoterminology is a paradigm that merges the building of formal Ontology with some of the fundamental tenets of the discipline of Terminology. The Semantic Web for Cultural Heritage chapter mainly deals with issues arising when Cultural Heritage data, such as data in the domain of Chinese vases, are expressed in Semantic Web standards, as well as related models, such as the Concept Reference Model of the International Council of Museums-ICOM, i.e., CIDOC-CRM, the Europeana Data Model (EDM), and the Art and Architecture Thesaurus (AAT), recently expressed as Linked Open Data to allow linking.

Part III presents the knowledge in the domain of ceramics, especially, Chinese ceramics of the Ming and Qing dynasties. The chapter on the basic knowledge of the ceramics chapter focusses on aspects of these cultural objects such as glaze, period, ornamentation, kiln, and decoration craft. The Chinese ceramics of the Ming and Qing dynasties chapter means to present the reason for choosing Ming and Qing dynasties and to present the research objects, as well as introduce the Chinese terms denoting these objects.

Part IV is the creation of an ontoterminology of Chinese ceramic vessels, which includes four chapters. The methodology chapter proposing a term-and-characteristic guided approach. The TAO CI ontology authoring chapter presenting the building of the ontology, which includes a linguistic dimension and a conceptual dimension of the ontology in OWL, built using the Protégé ontology editor. The TAO CI ontology description chapter states the classes, properties, and annotation of the TAO CI ontology. Finally, the ontology evaluation chapter describes the TAO CI ontology evaluation by OOPS!, OntoMetrics, and competency questions.

Part V is the TAO CI website to display the TAO CI project, TAO CI ontology, and E-dictionary based on the TAO CI ontology.

Part VI is the conclusion of this thesis and future work.

Research Topics Map

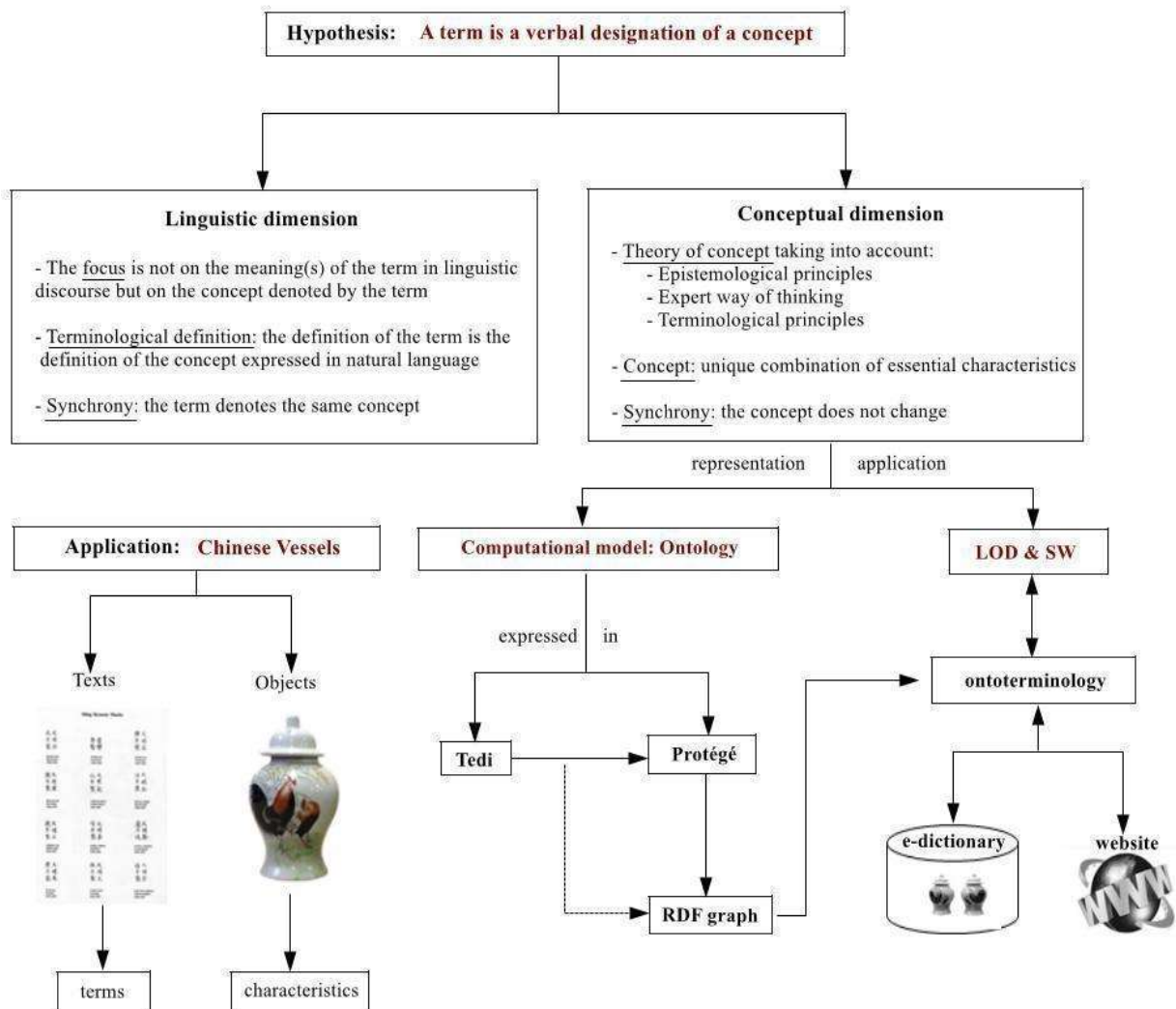


Figure 1. 1. The research topics map.

PART II: STATE OF THE ART

Chapter 1. Terminology

1.1 Definitions

We purport that there are three types of definitions useful for our theorizing: definition of name, of thing, of word. The definition of (proper) name assigns a fixed meaning to a unique object. The definition of thing is about the object denoted by the term. The definition of word is the meaning of a word in discourse (Antoine & Pierre, 1996). While lexicography focuses on defining words (rather than concepts), and the encyclopedias and terminologies are concerned with domain knowledge, ISO 704 highlights that “a *definition* shall define the *concept* as a unit with a unique *intention* and *extension*” (ISO 704, 2009). The intention, created by a unique combination of characteristics, should identify the concept and differentiate it from other concepts. ISO 1087-1 defines “definition” as “representation of a concept by an expression that describes it and differentiates it from related concepts” (ISO 1087-1, 2019, p. 6). Sager also presented the same idea: “A terminological definition provides a unique identification of a concept only with reference to the conceptual system of which it forms part” (Sager, 1990, p. 39). In regard to the term definition, C. Roche (2015) presented the distinction among these three levels of description. The term definition is closely related to the thing definition. “Term definition and thing definition differ in the sense that the former is a linguistic explanation, a meaning of a word of the discourse, while the latter is by nature an ontological definition in the sense that it presupposes the existence of the objects to which it refers” (Roche, 2015).

1.1.1 Terminology: definitions

The term “terminology” has more than one definitions. As Felber notes, three different concepts of “terminology”:

*terminology*¹: *Terminology science*

Inter- and transdisciplinary field of knowledge dealing with concepts and their representations (terms, symbols, etc.)

*terminology*²: *Aggregate of terms, which represent the system of concepts of an individual subject field.*

*terminology*³: *Publication in which the system of concepts of a subject field is represented by terms* (Felber, 1984).

In the first definition of the terminology, we refer to it as a discipline. The Austrian E. Wüster (1898-1977), considered the founder of modern terminology, came from the field of engineering. Wüster is credited with systematizing terminology working methods, established principles of terminology processing, and summarized the key points of terminology data processing. He focused on the terminology as a tool to make science and technology communication unambiguous and compelling. Wüster noted that “it as an interdisciplinary field of study, relating to linguistics, logic, ontology and information science with the various subject fields” (Sager, 1990, p. 2).

The ISO 1087-1 defines the terminology as follows: 1) “set of designations and concepts belonging to one domain or subject; 2) terminology science (science studying terminologies, aspects of terminology work, the resulting terminology resources, and terminological data)” (ISO 1087-1, 2019, p. 10). The first sense is

closely related to the terminology definition of Felber (1984). The difference is that Felber focuses on the terms, while the ISO standard focuses on designations that include terms, symbols, and appellations. For the term “term” definition, the ISO 1087-1 presents it as a “designation that represents a general concept by linguistic means” (ISO 1087-1, 2019, p. 6).

1.1.2 Concept: definitions

A *concept* is the basis of terminology work. The term “concept” has various definitions in different domains. Cognitive science focuses on the concept’s logical and psychological structure and putting them together to form thoughts and sentences (Thagard, 2019). In contemporary philosophy, Margolis presented three views to understand *concepts*: 1) as mental representations; 2) as abilities; 3) as abstract objects; (Margolis & Laurence, 2006). Felber described concepts as “mental representations of individual objects” (Felber, 1984, p. 115). Grenon summarized the meaning of a concept as follows: (1) *an idea or a mental representation of objects in reality*; (2) *a general idea under which a multiplicity of things falls (let us call these conceptual universals)*; (3) *a Platonic idea existing as a perfect prototype of things in the world, but itself, in some sense, exterior to the world*; (4) *a class, set or collection*; (5) *a word*; (6) *the meaning of a word* (Grenon, 2008, p. 71).

A *concept* may serve only one individual object or a set of individuals (expressed by designations). A *concept* is, therefore, an element of thought, which is also its definition in the General Theory of Terminology (GTT). The ISO 704 standard distinguishes two types of concepts: an individual concept that corresponds to a unique object and a general *concept* that corresponds to a potentially unlimited number of *objects* which form a group by reason of shared *properties* (ISO 1087-1, 2019, p. 3). However, Roche showed that a concept is a unit of knowledge that involves a plurality of things, whatever the number (one, or more, or even zero) (Roche, 2012b).

In this thesis, we adopt the following definition of concept: *concept* is a “unit of knowledge created by a unique combination of characteristics” (ISO 1087-1, 2019). In this definition, we could infer that it prefers a *concept* as a unit of knowledge that is a stable set of essential characteristics. The ISO 704 also expresses the same idea: “the *concept* should be viewed not only as a unit of thought but also as a unit of knowledge” (ISO 704, 2009). Therefore, in our work, we will take the *concept* as a unit of knowledge in a particular field of knowledge.

1.1.3 What is a “characteristic” in Terminology?

Characteristics play a central role in terminology work: “*Characteristics* shall be used in the analysis of concepts, model conceptual systems, and the formulation of definitions” (ISO 704, 2009; Roche, 2012a). Felber defined a “*characteristic*” is “an element of a concept which serves to describe or identify a certain quality of an individual object” (Felber, 1984, p. 117). The *characteristic* is used to comprise a concept, describe a concept, and distinguish a conceptual system. Recall the concept definition of ISO 1087-1, a “unit of knowledge created by a unique combination of *characteristics*.” Through this definition, we can see that characteristics play an integral part in the concept. ISO 1087-1 supplies the definition of the *characteristic*: “abstraction of a *property*” (ISO 1087-1, 2019, p. 3). *Property* is the feature or quality of an object (ISO

1087-1, 2019). For example, a ceramic vase has a handle and red glaze. In reality, both the handle and the red glaze are the properties of the vase. If we abstract these two properties, they will become the handle and red glaze characteristics.

ISO 1087-1 distinguishes between *essential characteristics*, *non-essential characteristics*, and *delimiting characteristics* (ISO 1087-1, 2019). An essential characteristic is a characteristic of a concept that is indispensable to understand that concept (ISO 1087-1, 2019). The non-essential characteristic is a characteristic of a concept that is not indispensable to understand that concept (ISO 1087-1, 2019). The delimiting characteristics are “essential characteristics used for distinguishing a concept from related concepts” (ISO 1087-1, 2019). A *descriptive characteristic* belongs to non-essential characteristics and is another characteristic to describe an object and does not determine a concept. If we removed *descriptive characteristics*, the nature of the concept would not change. The *descriptive characteristic* expresses valued knowledge, and it should not be represented as a unary predicate (Roche, 2012a). For example, a ceramic vase is with *handles* and *red glaze*. The *handle* is an essential characteristic in regard to the shape of the vase and it is crucial as the decision about the kind of vase is partly based on the type of handle. The *red glaze* is a descriptive characteristic, as it does not determine what type of vase a particular vase is.

1.1.4 Relation definition

A *relation* is essential in building a concept system. In a conceptual system, a concept does not exist in isolation. As Felber notes: “Because concepts are composed of characteristics, they have direct relationships to other concepts, which have the same characteristics in their intensions. A concept also has indirect relationships to other concepts, if the individual objects, which they represent are contiguous” (Felber, 1984, p. 120). ISO 704 also presents the same idea: “Concepts do not exist as isolated units of thought but always in relation to each other” (ISO 704, 2009; Roche, 2012a). ISO presents at least two types of relationships that are hierarchical relations (generic relations, partitive relations) and associative relations to model a concept system in terminology work (ISO 704, 2009).

1.1.4.1 Hierarchical relation

“In a hierarchical relation, concepts are organized into levels of superordinate and subordinate concepts. For there to be a hierarchy, there must be at least one subordinate concept below a superordinate concept” (ISO 704, 2009). The hierarchical relation plays a vital role in ordering a conceptual system, which should be in order through hierarchical relations to identify the superordinate and subordinate concepts in the specific knowledge domain. As C. Roche notes, “It plays a central role insofar as they order the conceptual system and thus enables us to understand and master its complexity: science is the ordering of reality” (Roche, 2012b). The hierarchical relation includes two types: generic relations and partitive relations.

Generic relation: A generic relation exists on two concepts when the subordinate concept's intension includes the intension of the superordinate concept plus at least one additional delimiting characteristic (ISO 704, 2009). The generic relation is between the superordinate concept and the subordinate concept. The former is called a generic concept; the latter is named as a specific concept. The critical feature of generic relations is inheritance. Suppose concept A is the specific concept of generic concept B. In that case, concept A inherits all characteristics of concept B. Figure 2.1 shows a generic concept (pointing device) and a

specific concept (computer mouse). The computer mouse inherits all characteristics of a pointing device. For the specific concept (mechanical mouse, optomechanical mouse, and optical mouse), the concept of the computer mouse is generic.

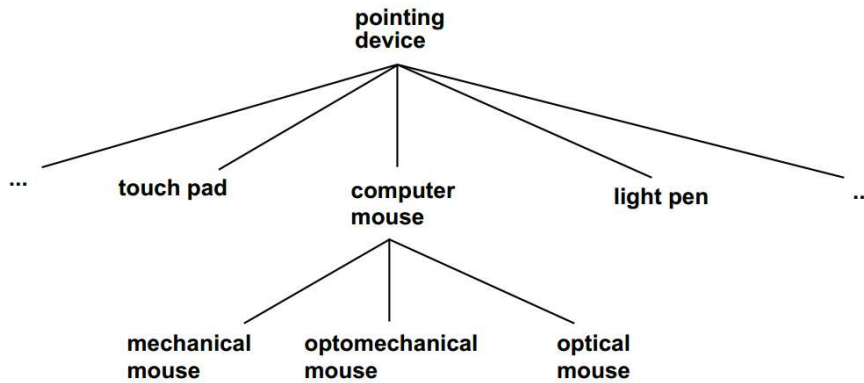


Figure 2. 1. Pointing device example of generic relations (ISO 704).

Partitive relations: A partitive relation is said to exist when the superordinate concept represents a whole, while the subordinate concepts represent parts of that whole (ISO 704, 2009). The partitive relations are the whole-part relation, and the part put together to constitute the whole. In partitive relations, the superordinate concepts are called comprehensive concepts. The subordinate concepts are called partitive concepts. Unlike the generic relations, the concepts in partitive relations do not have the inheritance. The partitive concept could not inherit the characteristic of comprehensive concepts. For example, Figure 2.2 shows that a mechanical pencil concept is comprehensive and represents a whole. The *barrel*, *lead-advance mechanism*, *lead*, and *refill eraser* are the partitive concept of the *mechanical pencil*, which are made up of *mechanical pencil* whole.

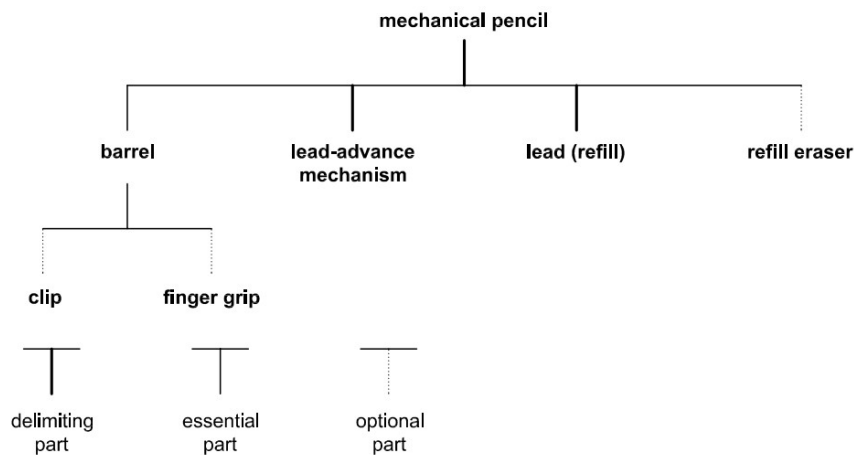


Figure 2. 2. The example of partitive relations (ISO 704).

1.1.4.2 Associative relation

An associative relation is a “relation between two concepts having a non-hierarchical thematic connection by virtue of experience” (ISO 1087-1, 2019). It is unnecessary to understand a connected concept, while

some associative relations exist when dependence is established between concepts with respect to their proximity in space or time (ISO 704, 2009). Here below are some examples of associative relations (Figure 2.3).

<i>Concepts</i>		<i>Associative relation</i>
milk carton	⇔ milk	container – contained
clicking	⇔ computer mouse	action – tool
gametes	⇔ zygote ⇔ zygospor	steps of a cycle
humidity	⇔ corrosion	cause – effect
baker	⇔ bread	producer – product
time	⇔ clock	quantity – measuring device
painter	⇔ brush	profession – tool employed
screw	⇔ screwdriver	object – tool for its manipulation

Figure 2. 3. Some examples of associative relations.

1.1.4.3 Ontological relation

Wüster classified relations into three different types: logical relationships, ontological relationships, and relationships of effect (Felber, 1984, p. 120). Ontological relationships are not examined in the ISO standards of terminology. They are indirect relationships between concepts (Felber, 1984, p. 135). In knowledge engineering, ontology is defined as a formal specification of concepts and their relations (Gruber, 1993; Roche, 2012b). The partitive relation is a type of ontological relationship.

1.1.5 Object definition

An object may be material or immaterial. ISO supplies the definition of objects: “An object is defined as anything perceived or conceived” (ISO 704, 2009). This definition includes two levels of knowledge. The first one is individual knowledge. “Such things are called individuals because each thing is composed of a collection of characteristics which can never be the same for another; for the characteristics of Socrates could not be the same for any other particular man” (Roche, 2012b; Warren, 1975). The second is conceptual knowledge. A concept is composed of characteristics, abstractions of properties that are features or qualities of an object. Thus, a concept is related to objects. In other words, a concept is an abstraction from a plurality objects.

1.2 Theories

1.2.1 Theories of Terminology

Terminology is not a new field of study.

Wüster proposed the General Theory of Terminology (GTT). The GTT was based on the significance of concepts and the distinction between them. The GTT theorized concepts, conceptual relations, relations between terms and concepts, and designations to concepts. According to Cabré (2003), GTT has the following contributions:

–The objective of international standardization is extended by suggestions of terminology development as part of language planning.

– Controlled synonymy is admitted. Wüster's posthumous work already concedes this point.

– A certain degree of synonymy is accepted though its avoidance is recommended in terminology intended to be standardized.

– Phraseology is added to the study of terminological units.

– The meaning of spoken forms is recognized in contexts of language planning.

– The model is made dynamic by introducing the description of the process of the formation of new terms.

– The representation of non-hierarchically-ordered conceptual structures is introduced.

On the other hand, what is not modified are:

– The priority of the concept over the designation, and consequently, its autonomy.

– The precision of the concept (monosemy), even though dimensions such as parameters of classification, are admitted.

– The semiotic conception of designations. (Cabré Castellví, 2003, p. 5).

With the development of GTT combined with other disciplines, researchers found it has limitations. For example, the GTT theory could not keep on the status of independence science. As Sager noted:

From philosophy and epistemology [terminology] has taken theories about the structure of knowledge, concept formation, the nature of definitions, etc.; from psychology, it has borrowed theories of perception, understanding, and communication, etc.; from linguistics, it has borrowed theories about the lexicon and its structure and formation; with lexicography, finally, it shares methods of structuring and describing words as well as experience about the presentation of information about words (Sager, 1990).

The critique of GTT was from cognitive science, language and communication science. “Cognition is the result of a mental process that leads to knowledge” (Kirsten, 2009, p. 23). How to understand reality is the foundation of the terminology theory. The cognitive theory of terminology should explain both reality and knowledge, how to form concepts and relationships with each other, and how the concept is related to the terms. As Cabré notes, “interlocutors play an important part in the construction of knowledge through discourse, and they also stress the omnipresence of culture (even scientific culture) in the perception of reality” (Cabré Castellví, 2003). From the language sciences perspective, GTT focuses on the concepts and concept relations, while terms are often vague and ambiguous. In language science, semantics and pragmatics play a crucial role. “Besides the formal aspect of language, linguistic models suitable for terminology must account for the cognitive and functional aspects” (Cabré Castellví, 2003). From the communication science, Cabré (2003: 182) starts from two assumptions: “a set of needs, a set of practices to resolve these needs and a unified field of knowledge”; “terminology operates with terminological units which are multi-dimensional and which are simultaneously units of knowledge, units of language and units of communication”. Cabré presents the terminological unit based on specialized communication or discourse and shows the theory of terminology as Figure 2.4.

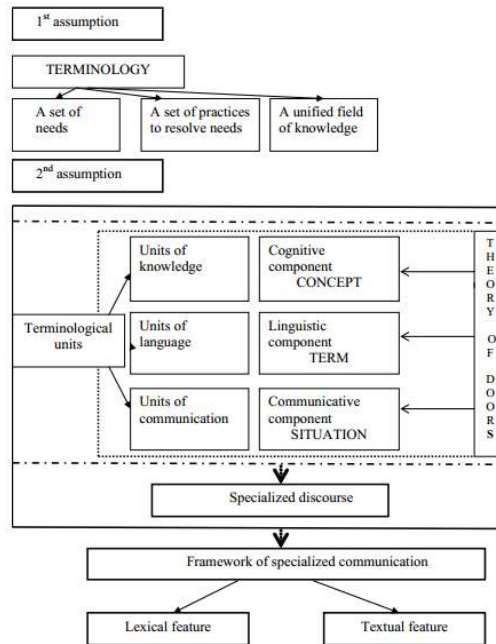


Figure 2. 4. The proposal for the Theory of Terminology as described by Cabré (Sageder, 2010).

Besides Wüster, who created modern terminology, there are four famous scholars in terminology theory: Alfred Schlomann from Germany, was the first one is to consider the systematic nature of special terms. The Swiss linguist Ferdinand de Saussure has drawn attention to the systematic nature of language. E. Dresen, a Russian early proponent of standardization. J. E. Holmstrom, an English scholar, who played a key role in disseminating UNESCO terminologies on an international scale” (Castellví, 1999, p. 6; Protopopescu, 2013).

1.2.2 ISO theory of Terminology

1.2.2.1 ISO Elements

ISO theories of Terminology aimed to provide standard guidelines of terminology work principles and methods, based on Wüster’s terminology theories. Figure 2.5 shows the connection between the main components of terminology work: concepts, objects, relations between concepts, and designations.

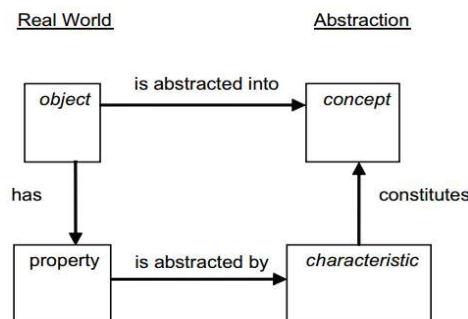


Figure 2. 5. The relation between real word and abstraction (ISO 704, 2009).

According to the ISO standards on terminology, a concept is made up of characteristics, while designations (terms, symbols, and appellations) denote concepts. Therefore, there is no term without concept. In terminology work, three types of designation need to be distinguished, namely, terms designating a general concept, appellations designating individual concepts, and symbols designating either general or individual concepts (ISO 704, 2009). Figure 2.6 shows the connections between those elements.

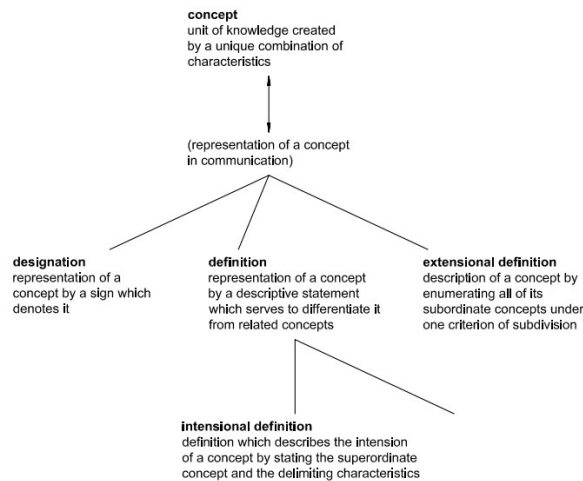


Figure 2. 6. Concept, definition, and designation in ISO (ISO 1087-1).

1.2.2.2 Graphic representations of components in ISO terminology work

In ISO terminology standard, it defines graphics to represent elements of terminology work. Boxes represent concepts with a grey background (ISO 1087-1, 2019) (Figure 2.7.a). Partitive relations are represented by means of rake diagrams (Figure 2.7.b). Associative relations are represented by arrow diagrams (Figure 2.7.c). Generic relations are represented by tree diagrams (ISO 1087-1, 2019) (Figure 2.7.d).

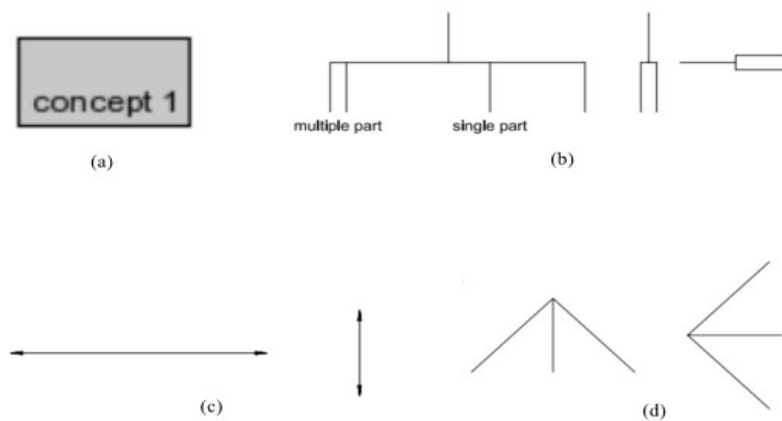


Figure 2. 7. Graphic representation of components in ISO terminology work.

1.3 Methods

1.3.1 Research methods

The general theory of terminology was formed by three classical schools - Vienna, Prague, and Soviet school - which had the different research approaches, such as the subject field-oriented approach, the philosophy, and the linguistic-oriented approach.

Subject field-oriented approach. It places the concepts in relation to other neighboring concepts and the correspondence concept term and the assignment of terms to concepts in the center of its reflections (Felber, 1984, p. 96). Its main feature is interdisciplinary knowledge of the domain knowledge—the GTT based on this approach.

Philosophy-oriented approach. It is similar to the subject fields oriented approach. It emphasizes the classification of concepts into philosophical categories (Felber, 1984, p. 96).

Linguistic-oriented approach. It is based on this idea that terminologies being subsets of a special language's lexicon are sublanguages of individual languages (Felber, 1984, p. 96). It applies linguistic tools to terminological phenomena, including lexicography.

However, Cabré further divided the working methods of terminology into terminology adapted to linguistic systems, translation-oriented terminology, and terminology oriented towards language planning.

Terminology is adapted to linguistic systems. As Caber notes, it was also divided into three types, according to the three work schools. The first one was the Vienna school of terminology, whose most salient feature was that it focused on concepts and steered terminological work towards the standardization of terms and concepts. The second one was the Czech school of terminology concerned with the terminology role in the structural and functional description of special languages (Castellví, 1999, p. 13). The third one was the Russian school of terminology that focused on the standardization of concepts and terms in multilingualism.

Translation-oriented terminology supports bilingual or multilingual translation.

Terminology oriented towards language planning is intended to introducing policies supporting the use of minority languages inside larger sociolinguistic areas.

1.3.2 Onomasiological vs. Semasiological process

The required terminology method is the onomasiological approach, which differs from the semasiological approach. Wüster defined terminology work as only the onomasiological starting with the concept and then moved on to the designation (term). The critical function of terms is to designate concepts. Apart from this function, one significant goal of the onomasiological method is to classify concepts into a conceptual system. According to GTT, concepts play an essential role in terminology work. Concepts and conceptual systems existed even before they were named. Thus the term is less important than concepts. The onomasiological process's advantage is that it operates with a structured quantity of concepts and does not represent concepts and terms in alphabetical order, but about their logical/ontological structures (Kirsten, 2009, p. 27).

The semasiological approach is the method of lexicography or particular lexicography. The semasiological approach starts with words as a linguistic sign and then moves on to the spectrum of its meanings. It is often used in lexicography and specialized lexicography. The semasiological approach does not permit a representation in related structures of knowledge but has to abide by alphabetical order (Kirsten, 2009, p. 29).

1.3.3 Synchronic vs. Diachronic approach

A significant difference in both Terminology and Lexicography or specialized lexicography is between the synchronic and diachronic approaches. Terminology focuses on the synchronized method, whereas Lexicography or specialized lexicography emphasizes the diachronic approach. As noted by Saussure, “The diachronic approach studies the development of language in time by paying attention to the affinity between languages and historical transmutations of sounds and by striving for the reconstruction of principal languages. It produces descriptions of how languages are genealogically related. The synchronic approach analyses the similarities and differences of languages at a given point of time by focusing on their structural features and characteristics and by using phonological, morphological, and syntactic explanations, including semantic and pragmatic aspects.” (Hämäläinen, 2014).

La linguistique synchronique s’occupera des rapports logiques et psychologiques reliant des termes coexistants et formant système, tel qu’ils sont aperçus par la même conscience collective. La linguistique diachronique étudiera au contraire les rapports reliant des termes successifs non aperçus par une même conscience collective, et qui se substituent les uns aux autres sans former système entre eux (Bally & Sechehaye, 1966).

Through their definition, we may know the synchronic method focuses on the logical and psychological relation between coexisting concepts making up a conceptual system. Whereas the diachronic approach focuses on the sequence of items, the same collective consciousness cannot perceive that, and these sequences replace each other instead of forming a system. The synchronization method results represent the subject fields organized by the system, and the diachronic approach results follow the alphabetic order.

1.4 Languages

The language is a “system of sounds, characters, symbols used for communication” (ISO 1087-1, 2019). The natural language is a “language that is or was in active use in a community of people, and the rules of which are mainly deduced from usage” (ISO 1087-1, 2019). The natural language is such that general language and special language can be accommodated within one natural language. It manifested the fundamental characteristics of language both in English and in chemical engineering, both in French and the language of physics. The difference between general and special language is the difference of degree rather than kind: the degree to which the fundamental characteristics of language are maximized or minimized in a special language. Compared with the general language, using a special language is more conscious and purposeful. In particular circumstances, the special language will intensify users' attention to this language. On the level of use, we look for more specific differentiating criteria (Sager et al., 1980). Language is a system of signs for communication, comprising vocabulary and rules (ISO 5127, 2017).

1.4.1 General language

All languages have a set of units and rules that all speakers know. The set of rules, units, and restrictions that form part of the knowledge of most speakers of a language make up the common or general language (Castellví, 1999, p. 59). A unit of the general language used is what we call "unmarked". The universal language could be considered the language, which is used in daily life to communicate. ISO 1087-1 defines it as "natural language characterized by the use of linguistic means of expression independent of any specific domain" (ISO 1087-1, 2019). The special language is part of the general language.

1.4.2 Special language

The definition of "special language" has always been controversial. As wrote Kocourek, "In our view, a special language is a sublanguage of what is known as natural language; a sublanguage enriched with short graphical items, that is, acronyms and ideograms integrated into the language according to its grammatical constraints." (Kocourek, 1982). Kocourek thought it was a sublanguage of natural languages and could not consider the specific subject field's situation. De Beaugrande (1987) provided a synthesis of some of the most representative positions (Castellví, 1999; De Beaugrande, 1987):

Special languages are linguistic codes that differ from the general language and consist of specific rules and units. In favor of this view, Hoffmann notes, "A complete set of linguistic phenomena occurring within a definite sphere of communication and limited by specific subjects, intentions, and conditions." (Hoffmann, 1979).

Special languages are variants of the general language. There are some experts to support it, such as Rondeau notes, "It must be noted that the terms 'special language' (specialized language) and 'common language' only refer to a subset of a language as a whole, that which consists of lexemes." (Castellví, 1999, p. 61).

Special languages are pragmatic subsets of language as a whole. Picht and Draskau also agree on this idea: "LSP is a formalized and codified variety of language, used for special purposes and in a legitimate context—that is to say, with the function of communicating information of a specialized nature at any level—at the highest level of complexity, between initiated experts, and, at lower levels of complexity, with the aim of informing or initiating other interested parties in the most economical, precise and unambiguous terms possible." (Picht & Draskau, 1985).

Because this thesis is based on ISO principles of Terminology, it adopts a definition of a special language that conforms to ISO's definition. "Special language is a language used in a subject field and characterized by the use of specific linguistic means of expression" (ISO/IEC FCD FCD 11179-1, 2003). The "subject field" is defined as "a branch of human knowledge. A subject field consists of a set of related concepts or concept systems. A set of designations make up a special language, which is used in a subject field" (ISO/IEC FCD FCD 11179-1, 2003). The ISO 1087-1 also presents a similar definition of "special language": "natural language used in communication between experts in a domain and characterized by the use of specific linguistic means of expression" (ISO 1087-1, 2019). The special language must consider these elements: users, the communicative circumstances, and the intentions of linguistic communication.

1.5 Tools

In terminology work, the purposes determine the different tools to be used. Here, we divide tools into several categories according to different purposes, including tools for building concept systems, searching terms, and extracting terms.

1.5.1 Tools for building a concept system

UML. As a unified software modeling language, UML has extensive modeling capabilities. UML, as graphic notation, is used for concept modeling in terminology work. ISO 24156-1 gives the guidelines for using UML notation in terminology work, whose scope is “a UML profile designed for this purpose is used to represent concepts and concept relations in terminology work” (ISO 24156-1, 2014). The concept system includes concepts, designation, characteristics, and concepts relations. ISO 24156-1 defines the mapping of UML symbols to terminological concepts. In UML, classes correspond to concepts of terminological work, and class names correspond to concepts' designations. Figure 2.8 shows to convert a class symbol to an ISO-compatible modeling template, and a concept is modeled by a rectangle which has equally two compartments, with the top one displaying the designation (ISO 10241-1) and the bottom one showing the characteristics (ISO 24156-1, 2014). The UML string *attribute = value* represents the characteristics. The UML compartment for class operations is not used in ISO 24156-1.

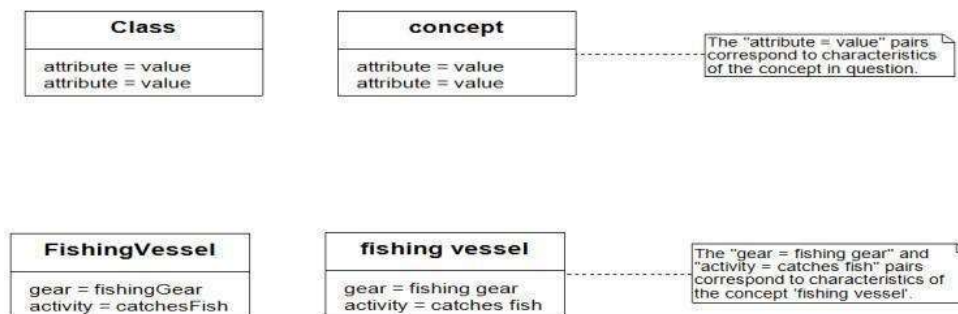


Figure 2. 8. Concepts, attributes, and characteristics in UML (ISO 24156-1).

The ISO notation adopts the UML notation in the following mode: the subdivision criterion is displayed by placing its name next to the relevant generic relation arrow(s), using a dashed line where more than one generic relation arrows are involved. The arrow(s), in turn, link(s) the generic concept to its specific concepts by the UML generalization symbol (ISO 24156-1, 2014). In the concept system, the characteristics are vital components of concepts. Figure 2.10 shows the concept modeling with characteristics in the ISO 24156-1.

In ISO 704, the relations include associative relations (Figure 2.9), generic relations (Figure 2.11), and partitive relations (Figure 2.12).

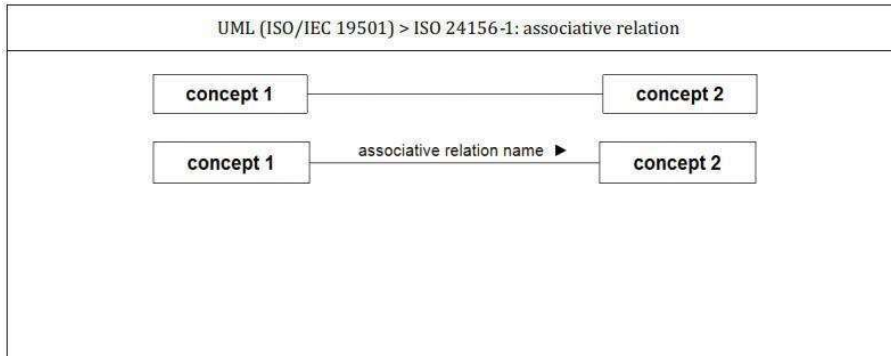


Figure 2. 9. Associative relation (ISO 704) in UML (ISO 24156-1).

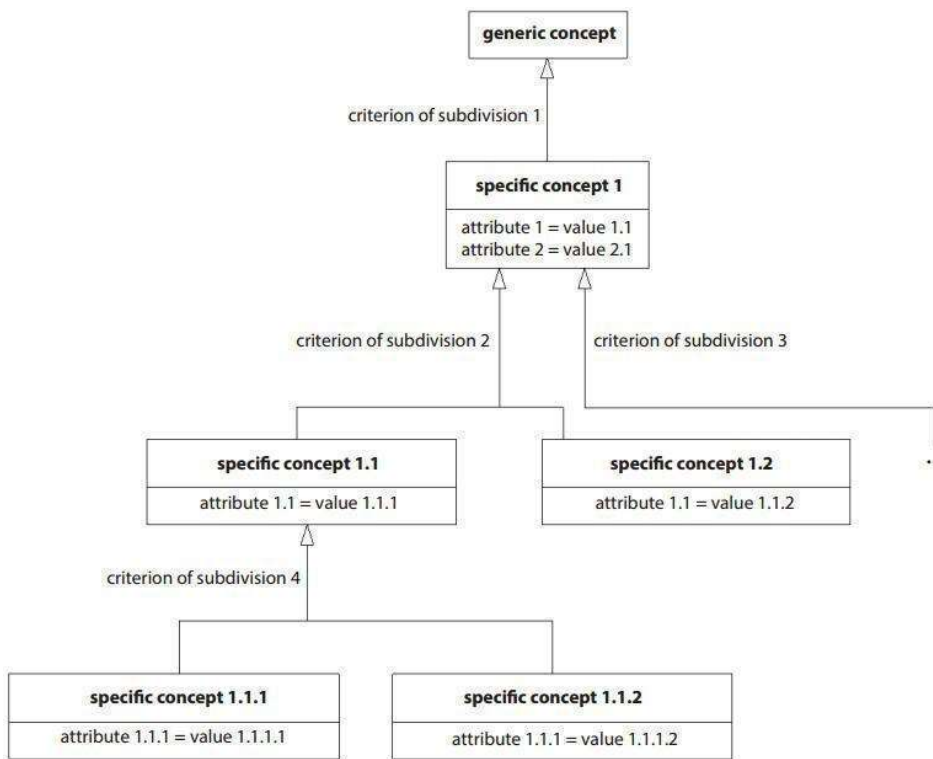


Figure 2. 10. Concept modeling with characteristics in the ISO 24156-1 user-defined UML profile (ISO 24156-1).

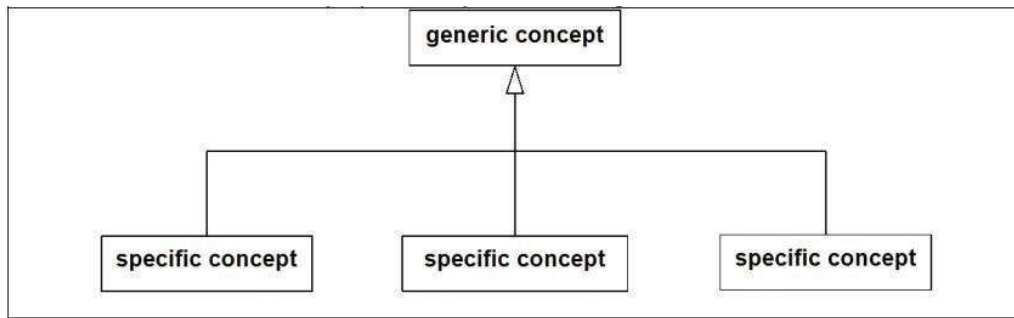


Figure 2. 11. Generic relations of ISO 704 in UML (ISO 24156-1).

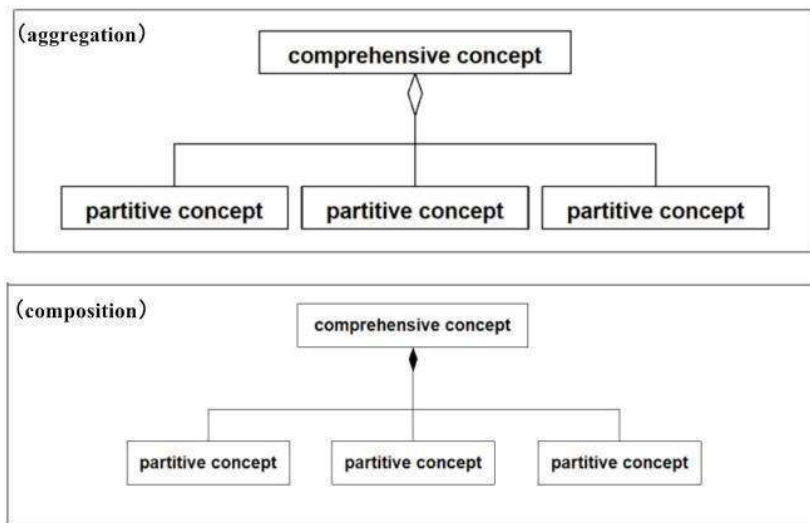


Figure 2. 12. Partitive relations of ISO 704 in UML (ISO 24156-1).

Cmap Tools. A tool resulting from research conducted at the Florida Institute for Human & Machine Cognition (IHMC). It empowers users to construct, navigate, share knowledge models represented as concept maps⁶. It allows users to create graphical nodes representing concepts efficiently and connect nodes using lines and linking words to form a network of interrelated propositions representing knowledge of a topic (Cañas & Novak, 2014). Figure 2.13 shows an example of a concept map built by means of Cmap tools.

⁶ <https://cmap.ihmc.us/>

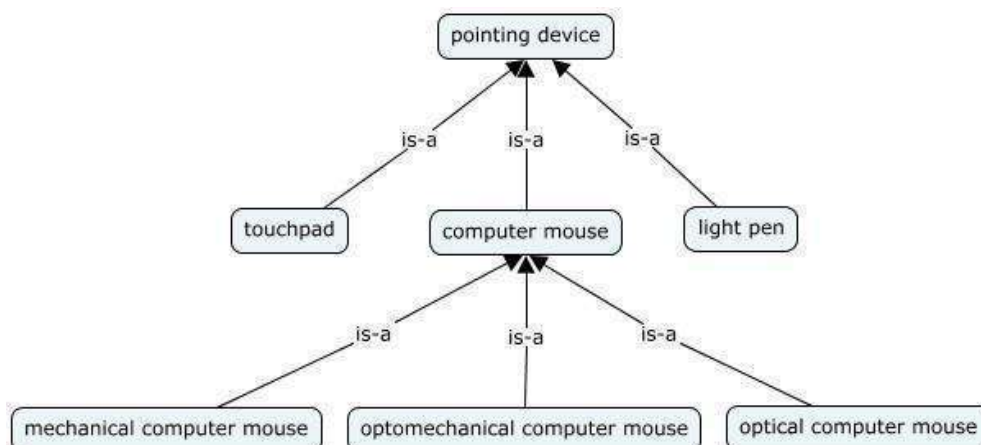


Figure 2. 13. An example of a concept model for pointing devices by the Cmap tools.

1.5.2 Terminological resources

When we need to find terms or multi-linguistic terms, the term resource plays an essential role.

IATE⁷ (Inter-Active Terminology for Europe) is the EU's inter-institutional terminology database. IATE has been used in the EU institutions and agencies since summer 2004 for the collection, dissemination, and shared management of EU-specific terminology⁸. The IATE includes the following legacy databases: Eurodicautom (European Commission), TIS (Council of the European Union), Euterpe (European Parliament), Euroterms (Translation Centre for the Bodies of the European Union), and CDCTERM (European Court of Auditors).

BabelNet⁹ is made up of more than 9 million entries¹⁰. It is a multi-linguistic encyclopedic dictionary with lexicographic and encyclopedic coverage of terms in 50 languages and an ontology that connects concepts and named entities in an extensive network of semantic relations.

WordNet¹¹ is an extensive lexical database of English. Nouns, verbs, adjectives, and adverbs are grouped into sets of cognitive synonyms (synsets), each expressing a distinct concept. Synsets are interlinked through conceptual-semantic and lexical relations¹².

Wikipedia¹³ is the world's largest collaboratively edited source of encyclopedic knowledge. It is a free encyclopedia that anyone can edit and currently contains 6,147,628 articles. It is related to many different domains, such as Arts, History, Society, Biography, Mathematics, Technology, Geography, and Science.

⁷ <https://iate.europa.eu/home>

⁸ https://ec.europa.eu/education/knowledge-centre-interpretation/conference-interpreting/terminology-tools-and-resources/eu-terminology-sources_en

⁹ <https://babelnet.org/>

¹⁰ <https://termcoord.eu/terminology-search-tools/>

¹¹ <https://wordnet.princeton.edu/>

¹² <https://wordnet.princeton.edu/>

¹³ https://en.wikipedia.org/wiki/Main_Page

EuroVoc¹⁴ is a multilingual, multidisciplinary thesaurus covering the activities of the EU. It includes 23 EU languages (Bulgarian, Croatian, Czech, Danish, Dutch, English, Estonian, Finnish, French, German, Greek, Hungarian, Irish, Italian, Latvian, Lithuanian, Maltese, Polish, Portuguese, Romanian, Slovak, Slovene, Spanish and Swedish) and three languages (Albanian, Macedonian and Serbian) of countries that are a candidate for EU accession¹⁵.

SDL MultiTerm store and manage terminology and share it with all those involved in applying terminology, including engineers, marketers, translators, and terminologists, ensuring consistent and high-quality content from the source to translation¹⁶. It provides the management and extraction of multi-language terms.

Term online (术语在线)¹⁷ It is a Chinese terminology management platform, which provides a searching function in English and Chinese. It includes terms of more than 100 disciplines in basic science, engineering and technology science, agricultural science, medicine, humanities, and social science, military science, and other fields. Besides, the book “Chinese-English Dictionary of the Document Information Management Terminology” (文件信息管理术语英汉词典) is about the terms of the document management, archive management, and information technology in Chinese and English, which could be used as a practical reference book for staff, researchers, university teachers, and students in the fields of e-government, e-commerce, information, document and archive management (An, 2010).

1.5.3 Tools for extracting terms

In the terminology work, it could be related to extracting terms from the corpus or Web. The following will introduce some tools for extracting terms from the corpus or Web.

Fivefilters¹⁸ is a free tool to extract relevant terms from text. It could convert a piece of text or a web article into a list of relevant terms. The application is intended to be a simple, free alternative to Yahoo's Term Extraction service. English is the only language supported at the moment.

Sketch Engine is an online tool created by Lexical Computing Ltd. for building and managing corpora, which, along with many corpus-processing features, includes terminology extraction¹⁹. Sketch Engine is used by linguists, lexicographers, translators, students, and teachers.

WebCorp²⁰ is a suite of tools that allows access to the World Wide Web as a corpus - an extensive collection of texts from which facts about the language can be extracted. WebCorp can be used by anyone who has an interest in language and how particular words and phrases are used, especially words and phrases which are too new or too rare to appear in any dictionary or standard corpus.

¹⁴ <https://eur-lex.europa.eu/TodayOJ/>

¹⁵ <https://en.wikipedia.org/wiki/Eurovoc>

¹⁶ <https://www.sdl.com/software-and-services/translation-software/terminology-management/sdl-multiterm/>

¹⁷ <http://www.termonline.cn/index.htm>

¹⁸ <https://www.fivefilters.org/term-extraction/>

¹⁹ <https://linguagrec.com/blog/2018/03/nine-terminology-extraction-tools-are-they-useful-for-translators/>

²⁰ <http://www.webcorp.org.uk/live/guide.jsp>

TermoStat²¹ is a term extraction tool that is based on a technique that compares specialized and non-specialized corpora to extract candidate terms.

AntConc is a freeware corpus analysis toolkit for coordination and text analysis. AntConc can export its results to a few different file formats, most notably text, HTML, or Excel files.

KEA²² is an algorithm for extracting keyphrases from text documents. It can be either used for free indexing or indexing with a controlled vocabulary. It covers six stages: 1) documents, 2) thesaurus, 3) extracting candidates, 4) feature, 5) building the model, 6) extracting keyphrases.

²¹ http://olst.ling.umontreal.ca/?page_id=91

²² <http://community.nzdl.org/kea/index.html>

Chapter 2. Ontology

2.1 Definitions

The term “ontology” has a different meaning in different disciplines. The most fundamental difference is possible between the philosophical sense and the computational sense. Usually, in the philosophical sense, the initial is capitalized, that is, “Ontology.” In a computational sense, ontology is often represented by “an ontology” or “ontologies.” The following will present the “ontology” definition in those two different communities.

2.1.1 Philosophical ontology definition

Ontology is the science of being. It is the actual existence of all things in the world. “Being” is a central question in Philosophy. In Aristotle's philosophy, the category of Ontology was created as a branch of Metaphysics, the philosophy discussing being. Merriam-Webster defines Ontology as “a branch of metaphysics concerned with the nature and relations of being.”²³ As a discipline, it focuses on the *nature* and *structure* of things per se, independent of any further considerations, and even independently of their actual existence (Guarino et al., 2009).

"In contemporary philosophy, formal ontology has been developed in two principal ways. The first approach has been to study formal ontology as a part of the ontology and analyze it using the tools and approach of formal logic: from this point of view, formal ontology examines the logical features of predication and various theories of universals. The use of the specific paradigm of the set theory applied to predication, moreover, conditions its interpretation.

The second line of development returns to its Husserlian origins and analyses the fundamental categories of object, state of affairs, part, whole, and so forth, as well as the relations between parts and the whole and their laws of dependence - once all material concepts have been replaced by their correlative form concepts relative to the pure 'something'. This kind of analysis does not deal with the problem of the relationship between formal ontology and material ontology." (Albertazzi, 1996, p. 199)

2.1.2 Computational ontology definition

In the computing sense, an ontology is a formalized representation of existence as a theoretical method. Merriam-Webster gives an ontology definition as “a particular theory about the nature of being or the kinds of things that have existence.”²⁴ At present, there is no unified standard definition of ontology in the different domains. For example, in the field of AI, Gruber defined ontology as “an explicit specification of a conceptualization (Gruber, 1993). To illustrate the ontology shared view, Borst presented the notion of ontology as “formal specification of a shared conceptualization” (Borst et al., 1997). Studer gave another definition: “an ontology is a formal, explicit specification of a shared conceptualization” (Staab & Studer,

²³ <https://www.merriam-webster.com/dictionary/ontology>

²⁴ <https://www.merriam-webster.com/dictionary/ontology>

2010, p. 2). These definitions focus on “specification”, “conceptualization”, “formal”, and “shared”. In the computer science and information science community, an ontology is a data model representing a set of concepts within a domain and the relationships between those concepts (Smith, 2004). In recent years, Ontologies are often used for AI, Semantic Web, and the building of Knowledge Bases. Ontologies are usually a set of vocabularies for defining the concepts and relationships (also referred to as “terms”) to describe and represent an area of concern²⁵. For example, Uschold gives an ontology definition as follows:

“An [explicit] ontology may take a variety of forms, but necessarily it will include a vocabulary of terms and some specification of their meaning (i.e., definitions).” (Uschold & Gruninger, 1996).

2.2 Theoretical foundations of ontologies

2.2.1 Main components of ontologies

According to Gruber (1993), there are five components in ontology modeling based on the frame and first-order logic. The five components are classes, relations, functions, instances, and axioms.

Classes. Classes represent concepts, which are often organized in taxonomies.

Relations. Relations between classes (Concepts) in ontology represent associations. Now it is called object properties, which have domain and range.

Functions. A function is a particular case of relations. Now it is defined as data properties, which have domain and range that is value.

Axioms. The axioms are used to model sentences that are always true and often represent knowledge that cannot be formally defined.

Instances. Instances are used to represent elements or individuals in an ontology.

2.2.2 Ontology types

In this paper, we adopt the two dimensions proposed by Guarino: the *level of detail* and *level of dependence* to classify ontologies. Guarino further divided them into different types.

According to the former dimension, the more detailed the ontology, the closer it is to the specified words' expected meaning. Simpler ontologies can be shared among users who agree with basic conceptualization. Therefore, Guarino distinguished between *reference ontologies* and *shareable ontologies*, or *off-line* and *on-line ontologies* (Guarino, 1997).

According to the latter dimension, Guarino distinguished between top-level ontologies, domain ontologies, task ontologies, and application ontologies (Figure 2.14) (Guarino, 1997).

²⁵ <https://www.w3.org/standards/semanticweb/ontology>

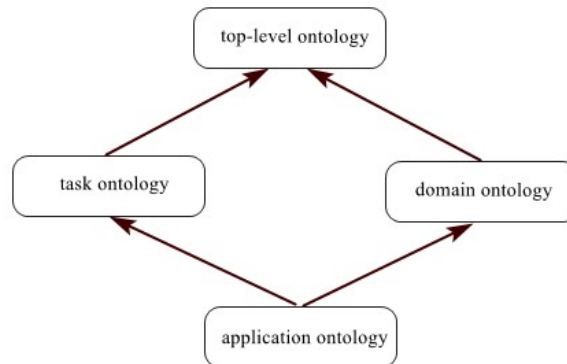


Figure 2. 14. The relation between those ontologies is based on the level of dependence.

Top-level ontology describes the general concepts, such as space, time, action, even, and object. The domain ontologies and task ontologies usually describe common domains or tasks through terms introduced in top-level ontologies. The application ontologies usually describe specialized domains based on specific domains and tasks.

Lassila and McGuinness (2001) distinguish ontologies in the following categories based on the richness of information and ontologies' internal structure: controlled vocabularies (catalog/ID), glossaries/terms, thesauri ("narrower term" relation), informal is-a hierarchies, formal is-a hierarchies, formal instances, frames (properties), value restriction, and general logical constraints (Lassila & McGuinness, 2001), as Figure 2.15 shows.

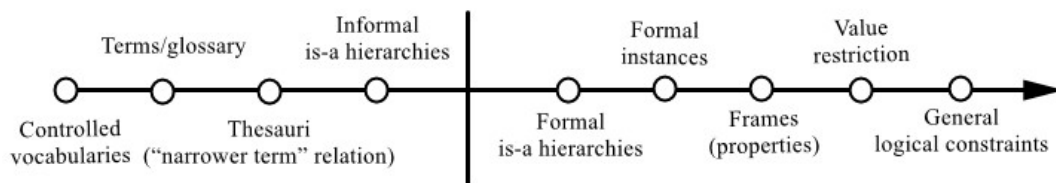


Figure 2. 15. Lassila and McGuinness's (2001) categorization.

2.2.3 Principles of ontology building

Gruber (1995) proposed several principles of designing ontologies to share knowledge and interoperate between programs based on a shared conceptualization.

Clarity: It is about the meaning of terms defined in the ontologies. The ontologies should communicate effectively and unambiguously by the term defined. The definitions should be objective and documented with natural language (Gruber, 1995).

Coherence: An ontology should be coherent and is consistent with the definitions. Axioms of the definition should be logical. The definition of informal concepts should be coherent.

Extendibility: An ontology should allow for extension. The ontology should enable users to define new vocabulary to meet the different application requirements.

Minimal encoding bias: The conceptualization should be specified at the knowledge level without depending on a particular symbol-level encoding (Gruber, 1995).

Minimal ontological commitment: Ontology should give as little ontology commitment as possible to support knowledge sharing activities. An ontology should make as few claims as possible about the world being modeled, allowing the parties committed to the ontology freedom to specialize and instantiate the ontology as needed (Gruber, 1995).

Arp, Smith & Spear (2015) also proposed eight criteria for designing an ontology. Those criteria are *realism*, *perspectivalism*, *fallibilism*, *adequate*, *the principle of reuse*, *The Ontology Design Process Should Balance Utility and Realism*, *The Ontology Design Process Is Open-Ended*, and *The Principle of Low-Hanging Fruit* (Arp et al., 2015). Apart from the above standards, those authors also put several principles of designing domain ontologies forwards. Following (Arp et al., 2015), five steps should be adapted:

1. *Determine the subject matter of the ontology; In this step, the scope of designing an ontology needs to be specified. Meanwhile, identifying existing ontology in the domain could be reused.*
2. *Gather information resources (e.g., Texts, existing ontologies) and identify the most relevant universals (i.e., Concepts) to be represented; In this step, the main work is that identifies the terms, concepts, and relationships between concepts in the domain ontology. The term could be from a textbook or abstracted from a corpus.*
3. *Organize these universals in a subsumption hierarchy—the universal need to organize in a hierarchy according to their relation. The analysis result may consist of step 4.*
4. *Review the results to ensure coherence (both logical and scientific), compatibility with neighboring ontologies and intelligibility (e.g., By drafting natural language definitions);*
5. *Formalize the conceptualization through a machine-readable language. This step is the task of iterative encoding of the ontology through logical formalization.*

2.2.4 Ontology evaluation

2.2.4.1 Definition of ontology evaluation

Generally, ontology evaluation is the problem of assessing a given ontology for a particular criterion of application, typically determining which of several ontologies would best suit a specific purpose (Brank et al., 2005). An interesting definition of ontology evaluation is “the activity of checking the technical quality of an ontology against a *frame of reference*” (Suarez-Figueroa & Gómez-Pérez, 2008). The frame of reference denotes a set of representative resources that sets a baseline value against which the ontology should be compared (Sabou & Fernandez, 2012). According to the reference framework, ontology evaluation is divided into ontology validation and ontology verification. Ontology validation refers to whether the meaning of the ontology definition expresses the real world for which ontology is created. The goal is to prove that the world model (if it exists and is known) is compliant with the world modeled formally (Staab & Studer, 2010, p. 256). It answers the question: “Are you producing the right ontology?”. Ontology verification refers to building the ontology correctly, that is, ensuring that its definitions implement the ontology requirements and competency questions correctly, or function correctly in the real world (Staab & Studer, 2010, p. 256). It answers the question: “Are you producing the ontology in the right way?”.

Verification and validation are two different aspects of ontology evaluation, but they are both critical. Ontology validation is an integral part of assessing the quality of an ontology, and usually, the only way to assure the correctness of the knowledge is encoded in the ontology (Staab & Studer, 2010, p. 256). However, most validation approaches require the close cooperation of domain and ontology engineering experts. Validation is not performed automatically. Ontology verification focuses on automatic evaluation methods.

2.2.4.2 Criteria of ontology evaluation

Ontology evaluation is an essential work between the ontology development process. According to different ontologies' objectives, there are two kinds of evaluation: technical (carried out by the developer) and users' evaluation. However, *quality* and *correctness* are essential aspects (Hlomani & Stacey, 2014; Raad & Cruz, 2015). For the criteria of ontology evaluation, Gómez-Pérez (2004) proposed five criteria: consistency, completeness, conciseness, expandability, sensitiveness. Other authors expressed a more comprehensive standard: accuracy, completeness, conciseness, adaptability, clarity, computational efficiency, and consistency (Gangemi et al., 2005; Raad & Cruz, 2015; Vrandečić, 2009). One suitable ontology does not perform equally well concerning all these criteria (Staab & Studer, 2010, p. 294). Therefore, the evaluator's first task is to choose the criteria relevant for the given evaluation and then choose the proper evaluation methods to assess how well the ontology meets these criteria (Staab & Studer, 2010, p. 295).

2.2.4.3 Method of ontology evaluation

There are different methods to evaluate ontology. Grüninger & Fox (1995) proposed Competency Questions to evaluate the ontology because competency questions play an essential role in the ontology development lifecycle. Gómez-Pérez (1996; 2001) proposed METHONTOLOGY as a method to design and evaluate ontologies. Guarino and colleagues present the OntoClean method to evaluate ontologies, which focused on removing the wrong *subclass* of relations in taxonomies based on some philosophical notions (Welty & Guarino, 2001). Sabou and Fernandez proposed a NeOn methodological guided to evaluate stand-alone ontologies and ontology networks (Sabou & Fernandez, 2012). Some authors proposed ontology metrics to evaluate ontology quality, such as structural metrics, functional metrics, and usability-profiling (Burton-Jones et al., 2005; Gangemi et al., 2006). In this chapter, we will present the OntoClean and NeOn methodologies.

OntoClean is a methodology for validating the ontological adequacy of taxonomic relationships (Guarino & Welty, 2004). OntoClean is based on general notions: essence, rigidity, identity, unity, and dependence, which come from philosophy. A set of meta-properties, based on those notions, which place constraints to the relations between concepts in the hierarchy, are dealt with here below:

Essence and Rigidity. “A property of an entity is essential to that entity if it must be true of it is a possible world. A property is rigid if it is essential to all its possible instances” (Guarino & Welty, 2004). Rigidity is a particular form of essentiality. “**R**” represents the Rigidity. Being rigid is defined by (+**R**). Not rigid is represented by (-**R**).

Identity and unity. “In general, identity refers to the problem of being able to recognize individual entities in the world as being the same (or difference), and unity refers to being able to recognize all the parts that form an individual entity” (Guarino & Welty, 2004). Identity and unity are the most crucial notions in

OntoClean. “I” designates identity. If it carries an identity criterion, the designation is (+I). (-I) represents not having an identification criterion. “U” represents unity. (+U) represents a collective unity criterion, and (-U) does not take a collective unity criterion. (\sim U) means have anti-unity.

This methodology includes four stages from lower to top: 1) assigning metaproperties; 2) Focusing only on the rigid properties; 3) Evaluating the taxonomy according to principles based on the meta-properties; 4) Considering non-rigid properties; 5) Completing the taxonomy with other concepts and relations (Bautista-Zambrana & Corcho, 2010, p. 188). This method analyzes the nature of properties related to subsumption relationships and validates the single subsumption relation according to the meaning of meta-properties defined.

NeOn: It is a methodology to build an ontology and considers multiple facts: the existence of multiple ontological resources, collaborative ontology development, reuse of knowledge base, and dynamic dimension. This methodology includes the ontology evaluation guidelines, which could be seen as a consequence of different activities (Figure 2.16).

Task 1. Selecting individual components of the ontology network. The main work of task 1 is to identify the components of the ontology that needs to be evaluated, such as ontology statements and ontology relations (Sabou & Fernandez, 2012).

Task 2. Selecting an evaluation goal and approach. For evaluating individual ontologies, the team needs to decide the evaluation's goal and select an appropriate evaluation approach (Sabou & Fernandez, 2012).

Task 3. Identifying a frame of reference and evaluation metric. Although in task 2 the team of developing ontology made the goals and approach, in Task 3, the team needs to select the evaluation's concrete ingredients, including a frame of reference and evaluation metrics (Sabou & Fernandez, 2012).

Task 4. Applying the selected evaluation approach. The core work is to apply the evaluation approach in experiments and implement software tools in this task.

Task 5. Combining and presenting individual evaluation results. The final task is to present the evaluation results appropriately for possible corrections and/or additions, improvements, and future evolution of the ontology network (Sabou & Fernandez, 2012).

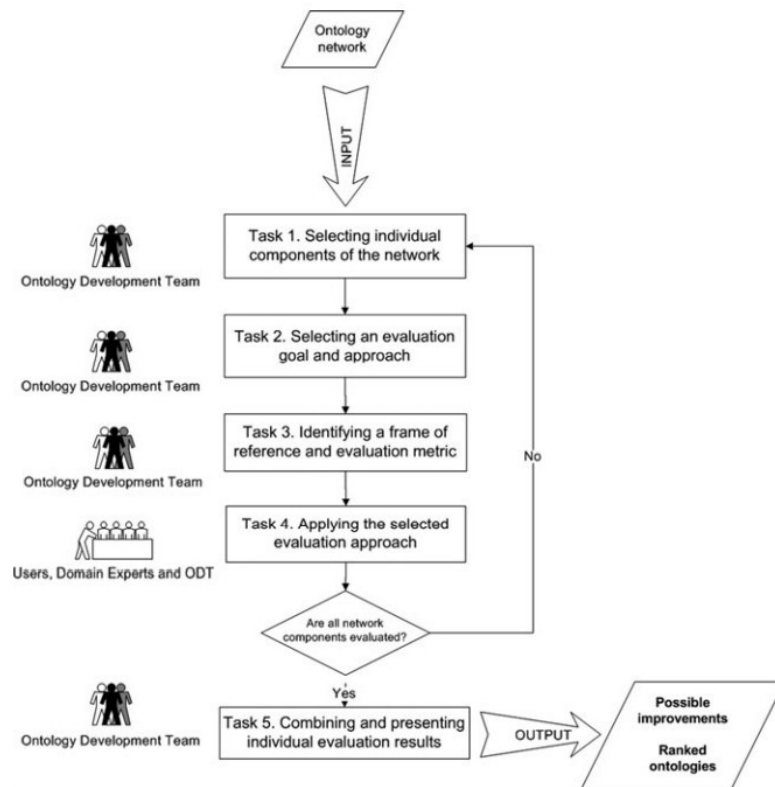


Figure 2. 16. Workflow and tasks for evaluating ontology networks (Sabou & Fernandez, 2012).

2.2.4.4 Tools for ontology evaluation

There are different tools for ontology evaluation. For example, Fernández-López & Gómez-Pérez (2012) presented ODEClean, a plug-in for WevODE. ODEval was supplied to evaluate RDFS, DAML+OIL, and OWL concept taxonomies (Corcho et al., 2004). OntoCheck (Schober et al., 2012), a plug-in for Protégé editor that helps clean up an ontology in terms of its lexical heterogeneity. However, most of them are not open source. This chapter will present two online tools.

OOPS! is a web-based online tool that can help users detect some of the most common pitfalls appearing when developing ontologies²⁶. It provides two functions: one can either upload the URL of the ontology or the RDF file. OOPS! supplies three indicators of the result: critical, essential, minor for each pitfall. If the pitfall is signalled as critical, it is crucial to correct the pitfall. Otherwise, it could affect the ontology consistency, reasoning, applicability (Poveda-Villalón et al., 2014). If it signals as important, though not critical for ontology function, it is essential to correct this type of pitfall. Although it is not a problem if it is signalled as having minor pitfalls.

OntoMetrics is a web-based tool that validates and displays statistics about a given ontology²⁷. It allows uploading the ontology in *. RDF or *. OWL file or entering a URL of a document. The platform of

²⁶ <http://oops.linkeddata.es/>

²⁷ <https://ontometrics.informatik.uni-rostock.de/ontologymetrics/index.jsp>

OntoMetrics provides the following function: a web-interface to upload owl ontologies and compute the ontology quality metrics; download the result of ontology quality metrics in the XML file; the semantics and the calculation of the ontology quality metrics are explained in a dedicated wiki (Lantow, 2016).

2.3 Languages

A language is required for encoding ontology. According to different goals and criteria, there are many different ontology languages divided into two distinct categories: traditional ontology languages and Web-based ontology languages (Su & Ilebrikke, 2002). The former includes first-order predicate logic (KIF, CycL), description logic (DL) based languages (Loom), frame-based languages (Ontolingua, F-logic, and OCML) (Kalibatiene & Vasilecas, 2011; Su & Ilebrikke, 2002). The latter includes OIL, DAML+OIL, OWL, RDF+RDFS, and SHOE. Web-based ontology languages often use marking schemes to encode knowledge. The most commonly used marking language is XML. This thesis focuses on the web-based ontology languages, which will be presented in the following.

Ontology Interface Layer (OIL) is based on concepts developed in Description Logic (DL) and frame-based systems and is compatible with RDFS (Fensel et al., 2000). Ontologies play an essential role in the exchange of data, information, and knowledge among different domains. OIL is intended as a specific standard for supporting ontologies, such as a role.

“This language has been designed such that:

(1) it provides most of the modeling primitives commonly used in frame-based and DL oriented Ontologies;

(2) it features simple, clean, and well-defined first-order semantics;

(3) automated reasoning support (e.g., class consistency and subsumption checking) can be provided. The FaCT system [10], a DL reasoner developed at the University of Manchester, can be, and has been, used to this end [11].” (Broekstra et al., 2001)

An ontology in OIL needs to distinguish three layers, which are the object-layer, first-meta layer, and second-meta layer. The object layer consists of individuals describing ontology. The first-meta layer is an actual ontological definition provided and is also called an ontology definition. The second-meta layer is concerned with ontology features description, such as name, project, date, and authority, and is also named as ontology container. OIL focuses on ontology definition and ontology containers. For example, Figure 2.17 shows an ontology in OIL.

<pre> ontology-container title "African Animals" creator "Ian Horrocks" subject "animal, food, vegetarians" description "A didactic example ontology describing African animals and plants" description.release "2.0" publisher "I. Horrocks" type "ontology" format "pdf" identifier "http://.../oil-rdfs.pdf" source "http://www.africa.com/" language "en-uk" ontology-definitions slot-def eats inverse is-eaten-by slot-def has-part inverse is-part-of properties transitive slot-def weight range (min 0) properties functional slot-def colour </pre>	<pre> range string properties functional class-def animal class-def plant disjoint animal plant class-def tree subclass-of plant class-def branch slot-constraint is-part-of has-value tree class-def leaf slot-constraint is-part-of has-value branch class-def defined carnivore subclass-of animal slot-constraint eats value-type animal class-def defined herbivore subclass-of animal slot-constraint eats value-type (plant or (slot-constraint is-part-of has-value plant)) </pre>	<pre> disjoint carnivore herbivore class-def mammal subclass-of animal class-def elephant subclass-of herbivore mammal slot-constraint eats value-type plant slot-constraint colour has-filler "grey" class-def defined african-elephant subclass-of elephant slot-constraint comes-from has-filler Africa class-def defined indian-elephant subclass-of elephant slot-constraint comes-from has-filler India disjoint-covered elephant by african-elephant indian-elephant instance information instance-of Africa continent instance-of Asia continent related is-part-of India Asia </pre>
---	--	---

Figure 2. 17. An example ontology in OIL (Jeen Broekstra, 2001, p. 5).

DAML+OIL. OIL is the first language that combines description logic, framework language, and web standards. DAML is an extension of RDF in object-oriented and framework based knowledge. Combining these two languages is an ontology language designing for the semantic web to describe domain structure. DAML+OIL is a semantic markup language for Web resources²⁸. DAML + OIL adopts the object-oriented method, uses the domain and attribute to describe the structure of the domain, and uses the axiom to declare the class and attribute features. Although DAML + OIL is based on RDF / RDFS, it is different from RDF. DAML + OIL is not a data model, but a structural language used to limit and describe the RDF data model's data. It can also be considered that DAML + OIL is another RDFS language or an extension of RDFS (McGuinness et al., 2002). For example, Figure 2.18 is the Wine class and MyFavoriteDrink wine class in DAML+OIL.

```

<daml:Class rdf:ID = "Wine">
<rdfs:subClassOf rdf:resource = "Drink"/>
<rdfs:subClassOf>
<daml:Restriction>
<daml:onProperty rdf:resource =
"hasWineColor"/>
<daml:toClass rdf:resource = "WineColor"/>
</daml:Restriction>
</rdfs:subClassOf>
</daml:Class>

<Wine rdf:ID = "MyFavoriteDrink">
<has WineColor rdf:resource = "Red"/>
</Wine>

```

Figure 2. 18. Wine class and MyFavoriteDrink class (McGuinness et al., 2002).

Resource description framework (RDF) is a data model that uses XML syntax to describe the features of web resources and the relationship between resources. It provides interoperability between applications that exchange machine-processable information on the Web (Broekstra et al., 2001). RDF is also often used to describe a specific domain's formal conceptualization and exchange data on the web. A resource could be anything, such as a person, location, picture, and document. RDF expresses those resources in a statement, of whose structure is: <subject> <predicate> <object> (Figure 2.19). The subject is the identifier of a resource. The predicate is the property or attributes that the subject must be expressed. The object is the

²⁸ <https://www.w3.org/TR/daml+oil-reference>

value of the predicate reference to the subject. In RDF, using the URI identifies the resources. For example, A statement that shows the entities “Kobe Bean Bryant” and “Philadelphia” linked through the property “birthPlace” is formally represented in RDF (Figure 2.20).

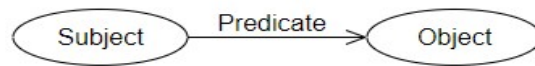


Figure 2. 19. Triple of RDF.

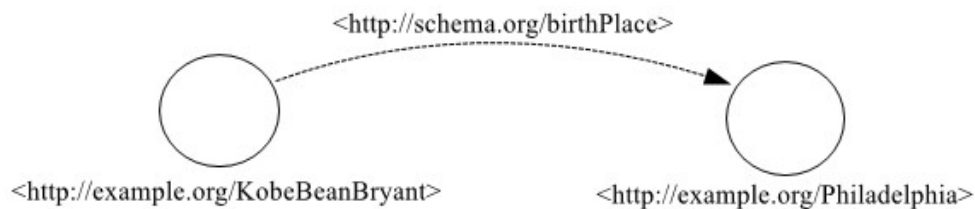


Figure 2. 20. An example of an RDF statement.

RDF is a relation model, but it is flexible and extensible. It allows adding relations dynamically without needing to modify the schema and repetition of triples. Therefore, RDF is easy to use when merging data from different resources. Meanwhile, RDF has become a model to build a shared vocabulary for describing shared metadata of resources, which is relevant to the Simple Knowledge Organization System (SKOS) that is an RDF-based extensible family of languages designed for representing any structured vocabulary (such as thesauri, classification schemes, taxonomies.) (Isaac & Summers, 2009).

Resource description framework Scheme (RDFS) is a kind of ontological language and provides a data-modeling vocabulary for RDF data and is a semantic extension of RDF²⁹. RDFS include several critical vocabularies: `rdfs:class` is used to define class; `rdfs:domain` is used to indicate which category the property belongs to; `rdfs:range` is used to describe the value type of the attribute; `rdfs:subClassOf` is used to describe the parent class of this class; `rdfs:subProperty` is used to describe the parent property of this property. However, RDFS is not a suitable foundation for the semantic web. Its expressive ability to describe resources in full detail is too weak. Moreover, to effectively apply these descriptions to the automatic processing process, it also needs to have an automatic reasoning ability (such as determining the semantic relationship between different terms in grammar), which RDFS lacks (Horrocks, 2002).

Ontology Web Language (OWL) is a Semantic Web language designed to represent rich and complex knowledge about things, groups of things, and relations between things³⁰. OWL facilitates greater machine interpretability of Web content than supported by XML, RDF, and RDF Schema (RDFS) by providing additional vocabulary and formal semantics³¹. OWL consists of three language variants of increasing expressive power: OWL Lite, OWL DL, and OWL Full. OWL Lite aims initially to support those users needing a classification hierarchy and simple constraints³². OWL DL corresponds with description logic.

²⁹ <https://www.w3.org/TR/rdf-schema/>

³⁰ <https://www.w3.org/OWL/>

³¹ <https://www.w3.org/TR/owl-features/>

³² <https://www.w3.org/TR/owl-guide/>

OWL Full preserves the compatibility with RDF Schema and different semantics from OWL Lite or OWL DL.

Although OWL has been successful, it has some limitations. For example, OWL lacks a suitable set of built-in datatypes because it is based on XSD set for data types. OWL could not meet some small and useful functional requirements of users. To solve these questions, OWL 2 was proposed, which is an extension of OWL. OWL 2 ontologies provide classes, properties, individuals, and data values and are stored as Semantic Web documents³³. OWL 2 ontologies can be used along with information written in RDF, and OWL 2 ontologies themselves are primarily exchanged as RDF documents³⁴. Compared with OWL 1, OWL 2 increased extra features and rationale. For example, syntactic sugar (making statements easier to say), new constructs (increasing expressivity), extended data types, and annotation. The OWL 2 also includes three sub-languages: OWL 2 EL, OWL 2 QL, and OWL 2 RL. OWL 2 EL enables polynomial-time algorithms for all the standard reasoning tasks³⁵. OWL 2 QL allows conjunctive queries to be answered in LogSpace using standard relational database technology³⁶. OWL 2 RL enables polynomial-time reasoning algorithms using rule-extended database technologies operating directly on RDF triples³⁷. Figure 2.21 shows an overview of the OWL 2 language, showing its main building blocks and how they relate to each other³⁸. The ellipse in the center represents the abstract notion of an ontology. At the top, various concrete syntaxes are used to serialize and exchange ontologies. At the bottom, two semantic specifications are to define the meaning of OWL 2 ontologies. Figure 2.22 shows an example of an OWL ontology.

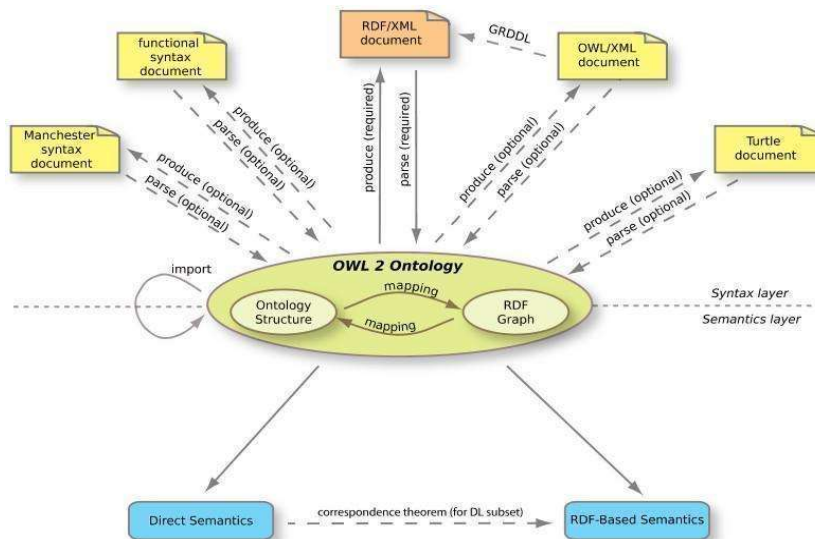


Figure 2. 21. The structure of OWL 2.³⁹

³³ <https://www6.inrae.fr/mia-paris/content/download/4478/42224/version/1/file/cours+OWL.pdf>

³⁴ <https://www.w3.org/TR/owl2-overview/>

³⁵ <https://www.w3.org/TR/owl2-overview/#ref-owl-2-new-features>

³⁶ <https://www.w3.org/TR/owl2-overview/#ref-owl-2-new-features>

³⁷ <https://www.w3.org/TR/owl2-overview/#ref-owl-2-new-features>

³⁸ <https://www.w3.org/TR/owl2-overview/>

³⁹ <https://www.w3.org/TR/owl2-overview/>


```

<rdf:RDF
  xmlns:owl ="http://www.w3.org/2002/07/owl#"
  xmlns:rdf ="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:xsd ="http://www.w3.org/2001/XMLSchema#">
  <owl:Ontology rdf:about="">
    <rdfs:comment>An example OWL ontology</rdfs:comment>
    <owl:imports rdf:resource="http://www.mydomain.org/persons"/>
    <rdfs:label>University Ontology</rdfs:label>
  </owl:Ontology>
  <owl:Class rdf:ID="academicStaffMember"></owl:Class>
  <owl:Class rdf:ID="associateProfessor">
    <rdfs:subClassOf rdf:resource="#academicStaffMember"/>
  </owl:Class>
  ...
</rdf:RDF>

```

Figure 2. 22. Ontology in OWL.⁴⁰

Simple HTML Ontology Extension (SHOE) is a knowledge representation language that makes HTML annotate with semantics. It makes the machine-readable semantic knowledge in web pages.

“SHOE's basic structure consists of ontologies, entities which define rules guiding what kinds of assertions may be made and what kinds of inferences may be drawn on ground assertions, and instances, entities which make assertions based on those rules. Because SHOE exists in a distributed environment with little central control, SHOE treats assertions as claims being made by specific instances instead of facts to gather and intern as generally-recognized truth.

SHOE's syntax is a properly-compliant application extension of HTML; an almost identical XML syntax is also available. However, while SHOE's chief application is the annotation of web documents, SHOE is designed for more general distributed knowledge and distributed agent issues.” (Heflin & Hendler, 1999).

For example, Figure 2.23 displays an ontology in HTML.

⁴⁰ [https://www.scss.tcd.ie/Owen.Conlan/CS7063/06%20Introduction%20to%20OWL%20\(1%20Lecture\).ppt.pdf](https://www.scss.tcd.ie/Owen.Conlan/CS7063/06%20Introduction%20to%20OWL%20(1%20Lecture).ppt.pdf)

```

<HTML>
<HEAD>
  <TITLE>University Ontology</TITLE>
  Tell agents that we're using SHOE
  <META HTTP-EQUIV='SHOE' CONTENT='VERSION=1.0' >
</HEAD>
<BODY>
  Declare an ontology called "university-ontology".
  <ONTOLOGY ID='university-ontology' VERSION='1.0' >
  Borrow some elements from an existing ontology, prefixed with a "b."
  <USE-ONTOLOGY ID='base-ontology' VERSION='1.0' PREFIX='b'
    URL='http://www.cs.umd.edu/projects/plus/SHOE/base.html' >
  Define some categories and subcategory relationships
  <DEF-CATEGORY NAME='Person' ISA='b.SHOEntity' >
  <DEF-CATEGORY NAME='Organization' ISA='b.SHOEntity' >
  <DEF-CATEGORY NAME='Worker' ISA='Person' >
  <DEF-CATEGORY NAME='Advisor' ISA='Worker' >
  <DEF-CATEGORY NAME='Student' ISA='Person' >
  <DEF-CATEGORY NAME='GraduateStudent' ISA='Student Worker' >
  Define some relations; these examples are binary, but relations can be n-ary
  <DEF-RELATION NAME='advises' >
  <DEF-ARG POS=1 TYPE='Advisor' >
  <DEF-ARG POS=2 TYPE='GraduateStudent' ></DEF-RELATION >
  <DEF-RELATION 'age' >
  <DEF-ARG POS=1 TYPE='Person' >
  <DEF-ARG POS=2 TYPE='b.NUMBER' ></DEF-RELATION >
  <DEF-RELATION 'suborganization' >
  <DEF-ARG POS=1 TYPE='Organization' >
  <DEF-ARG POS=2 TYPE='Organization' ></DEF-RELATION >
  <DEF-RELATION 'works-for' >
  <DEF-ARG POS=1 TYPE='Person' >
  <DEF-ARG POS=2 TYPE='Organization' ></DEF-RELATION >
  Define a transfers-through inference over working for organizations
  <DEF-INFERENCE >
  <INF-IF >
  <RELATION NAME='works-for' >
  <ARG POS=1 VALUE='x' VAR >
  <ARG POS=2 VALUE='y' VAR ></RELATION >
  <RELATION NAME='suborganization' >
  <ARG POS=1 VALUE='y' VAR >
  <ARG POS=2 VALUE='z' VAR ></RELATION ></INF-IF >
  <INF-THEN >
  <RELATION NAME='works-for' >
  <ARG POS=1 VALUE='x' VAR >
  <ARG POS=2 VALUE='z' VAR ></RELATION ></INF-THEN >
  </DEF-INFERENCE >
</ONTOLOGY >
</BODY >
</HTML >

```

Figure 2. 23. Ontology in HTML.

2.4 Methods

There are many ontology building methods. Some of them are dependent on the experts' manual building. Others need the help of a machine learning algorithm or domain knowledge. It is not possible to list all the methods in this section. So, there is a list of some typical ontology building methods, such as Skeletal Methodology, IDEF-5, TOVE, METHONTOLOGY, CommonKADS, Lexicon-based ontology construction method, and Thesaurus-based domain ontology construction method.

Skeletal Methodology. At the beginning of ontological engineering, there is no standard methodology to build an ontology compared with knowledge engineering. To solve this question, Uschold and King (1995) proposed the Skeletal Methodology, which included four steps:

1. *Identify purpose;*
2. *Building ontology;*
 - *Ontology capture*
 - *Ontology coding*
 - *Integrating existing ontologies;*

3. Evaluation

4. Documentation (Uschold & King, 1995).

Integrated Definition for Ontology Description Capture Method (IDEF-5) is a software engineering method to develop and maintain functional, accurate domain ontologies⁴¹. IDEF-5 obtains the concept, attribute, and relation of objective existence using diagrams, language, and elaboration language and formalizes them into ontology. IDEF-5 is one of the IDEF families that include IDEFØ, IDEF1X, IDEF1, IDEF3, IDEF4, and IDEF5. IDEF-5 method has five activities of the ontology development process:

1. **Organizing and Scoping.** This activity involves establishing the purpose, viewpoint, and context for the ontology development project and assigning roles to the team members.

2. **Data Collection** This activity involves acquiring the raw data needed for ontology development.

3. **Data Analysis** This activity involves analyzing the data to facilitate ontology extraction.

4. **Initial Ontology Development** This activity involves developing a preliminary ontology from the acquired data.

5. **Ontology Refinement and Validation** This activity involves refining and validating the ontology to complete the development process. (Benjamin et al., 1994).

IDEF-5 method solves the crucial need by supplying a cost-effective mechanism to acquire, store, and maintain scalable and re-useable ontologies. The expected contribution of IDEF-5 is a way to guide and assist experts and engineers in building small and large reusable ontologies.

Common Knowledge Acquisition and Design System (CommonKADS) is the leading methodology to support structured knowledge engineering⁴². The knowledge-based system is an essential branch of artificial intelligence. In a knowledge-driven society, knowledge systems' requirements are getting higher and higher, such as the processing of sophisticated knowledge and fault tolerance. Knowledge engineering is not some kind of art or craft but is a scientific discipline that comprises developing different aspect models of knowledge. CommonKADS method includes three levels: context, concept, and artifact. Each level has a different technique or model (Schreiber et al., 1994) (Figure 2.24).

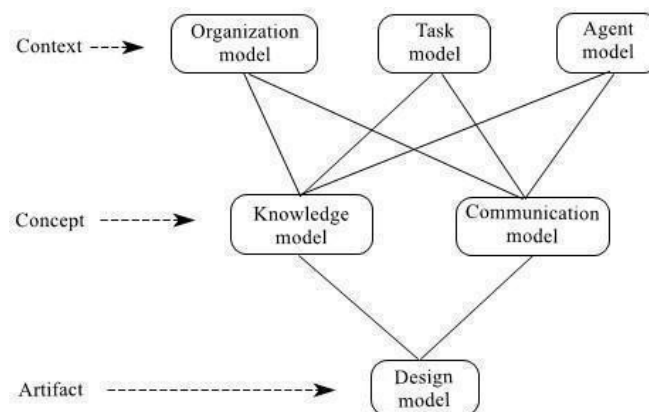


Figure 2. 24. CommonKADS model suite.

⁴¹ <https://en.wikipedia.org/wiki/IDEF5>

⁴² <https://commonkads.org/>

Toronto Virtual Enterprise (TOVE) method proposed was based on the TOVE project's experience, which is to represent a common-sense enterprise model. This method initially focuses on ontology reasoning in the enterprise community and focuses on constructing an information system to support the enterprise design and execution (Grüninger & Fox, 1995). The TOVE method has six activities of creating ontology, as follows in Figure 2.25:

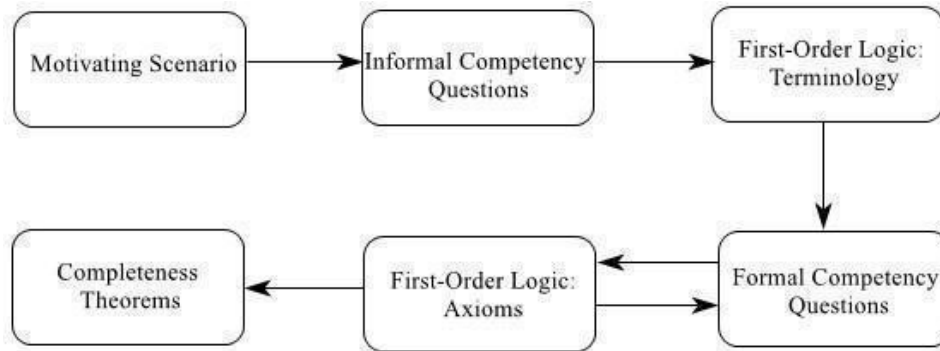


Figure 2. 25. Procedure for Ontology Design and Evaluation.

1. **Motivating Scenarios.** In this activity, it needs to answer why we developed this ontology. In other words, what problems does the enterprise encounter in a practical enterprise environment?
2. **Informal Competency Questions.** According to motivating scenarios, it needs to make an informal competency question, which the ontology needs to answer. Informal competency questions could also be used in ontology evaluation.
3. **First-order Logic: Terminology.** An ontology is a formal description of objects of reality. To express the definitions and constraints, we need the specification terminology to restate the competency questions.
4. **Formal Competency Questions.** When the informal competency questions and terminology specification are finished, the informal competency question will be formalized in the ontology with specified terms.
5. **First-order Logic: Axiom.** Axioms specify the definition of terms and constraints on their interpretations in the ontology (Grüninger & Fox, 1995). It is difficult for parties to design ontologies. Formal competency questions guide the process of axiom specification.
6. **Completeness Theorems.** It is an evaluation activity that assesses whether ontology could solve the competency questions completely.

TOVE method makes a significant contribution to ontology evaluation, but it does not give specific guidance of ontology application design principles.

METHONTOLOGY. Fernández-López (1997) proposed the METHONTOLOGY method to reduce the gap between ontological art and ontological engineering. It was applied to the chemical domain. METHONTOLOGY guides experts or engineers to build ontology from scratch, activities and in which order, and techniques to be used in each stage. This method includes six phases:

1. Specification. This phase will make a document about the purpose of the ontology, scope, level of formality of ontology, and other information in natural language.
2. Knowledge Acquisition. It is about how to acquire domain knowledge used in ontology. In other words, where does knowledge come from, such as books, experts, journals? The knowledge may be a list of terms and their meaning and relation between concepts.
3. Conceptualization. This activity will structure the domain knowledge in a conceptual model that describes the problem and its solution in terms of the domain vocabulary identified in the ontology specification activity (Fernández-López et al., 1997).
4. Integration. In this phase, it is about reusing the existing ontology. Finding the vocabulary defined in another ontology and reused them could avoid starting from scratch.
5. Implementation. Selecting a kind of language and tool implements ontology in the formalization.
6. Evaluation. There are many evaluation methods to evaluate ontology. The evaluation output should be all kinds of documents describing the technique used, errors, and competence ontology.
7. Documentation. The primary purpose of this phase is to build a summary document of ontology. The document could include all life cycles of the ontology developed and all information.

In METHONTOLOGY, the focus is on comprehensively addressing the maintenance stage of the ontology life cycle. However, other methods, such as TOVE do not take this stage into consideration (Jones et al., 1998).

Thesaurus-based domain ontology construction method. Because thesaurus contains rich domain concepts and certain semantic relations, it has a natural connection with ontology in the expression of knowledge structure and contains relatively complete terms in the field of this subject (Kang & Lee, 2001). So, many academic groups try to build the ontology based on the thesaurus, and the research focus is on the method of transformation from the thesaurus to ontology. Kang & Lee (2001) proposed a semi-automatic approach to build an ontology based on a thesaurus, computational dictionaries, and large corpora by means of extracting concepts, terms, and relations from those resources. After that, those concepts and relations insert into LIP ontology. Ven Eman introduced another method that transfers a full thesaurus into owl ontology, which builds a relation between concepts according to the concepts' relation in the thesaurus (ven Eman, 2005). However, the disadvantages that one has to tackle are concept repetition, both in the core ontology and the transformed ontology, and how to refine the original relationship of the thesaurus.

The lexicon-based ontology construction method is based on a representation scheme called the extended language lexicon (LEL) (Breitman & do Prado Leite, 2003). This method is intended to construct machine-processable ontologies. Many approaches focus on modeling aspects, but few methods concentrate on domain concepts and relationships. Based on their research background in requirements engineering (RE), Breitman and Leite (2003) proposed an ontology construction process centered on an established requirements elicitation strategy, whose focus is on application languages. The focus of this method is the process from Lexicon to ontology. The process includes six steps (Figure 2.26).

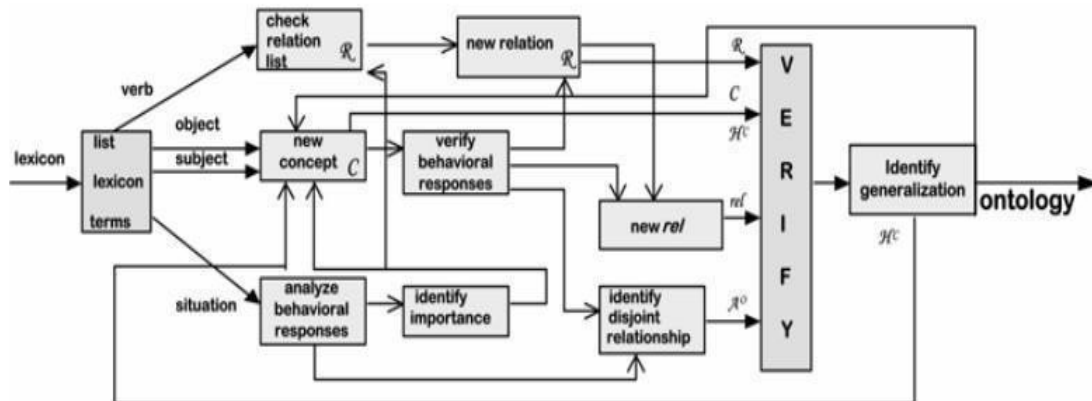


Figure 2. 26. Lexicon-based ontology construction process (Breitman and Leite, 2003).

This process is naturally bottom-up, which is the beginning of a concept and adds new properties and classes around it. The result is an interconnected concept network.

On-To-Knowledge Methodology is another method that supports the systematic introduction of knowledge management solutions into enterprises (Sure et al., 2004). For knowledge management applications, there are two essential processes: knowledge process and knowledge meta-process. The ON-To-Knowledge method presents to establish ontologies considering how to use these ontologies in knowledge management applications. This method includes the following five phases: feasibility study, kickoff, refinement, evaluation, application & evolution.

Feasibility study. In this phase, the principal work is to identify a problem and potential solutions and serve as decision support for enterprise or technical.

Kickoff. This phase is the beginning of building ontologies. The ontology requirements specification document (ORSD) needs to be finished in these phase. ORSD should guide the ontology engineer to determine the concepts and relations and hierarchical structure of the ontology. The outcome of this phase will be a semi-formal description of the ontology.

Refinement. The main work is the refinement of semi-formal ontology obtained in the Kick-off phase. Two approaches are top-down and bottom-up to model it. This phase's result is the “target ontology” that formalizes the initial semi-formal description of the ontology.

Evaluation. This phase will evaluate the ontology generated in the previous stage. The evaluation work will be from several perspectives: technology-focused evaluation, user-focused evaluation, ontology-focused evaluation, and formally evaluate ontologies.

Application & evaluation. The last phase is about the ontology application. The purpose of developing ontology is to solve the question of knowledge management applications. So, the ontology application is most important in knowledge management applications. After that, it needs to evaluate the result of applying ontology.

NeOn methodology does not prescribe a rigid workflow, but instead, it suggests a variety of pathways for developing ontologies (Suárez-Figueroa et al., 2012). It proposed the method based on the specific scenarios, which include the nine scenarios: *scenarios 1: from specification to implementation*; *scenarios 2: Reusing and re-engineering non-ontological resources*; *scenarios 3: Reusing ontological resources*; *scenarios 4: Reusing and re-engineering ontological resources*; *scenarios 5: Reusing and merging ontological resources*; *scenarios 6: Reusing, merging, and re-engineering ontological resources*; *scenarios 7: Reusing ontology design patterns (ODPs)*; *scenarios 8: Restructuring ontological resources*; *scenarios 9: Localizing ontological resources* (Suárez-Figueroa et al., 2012). As Figure 2.27 shows, directed arrows with associated numbered circles represent the different scenarios. Each scenario is decomposed into different processes or activities. Processes and activities are represented with colored circles or rounded boxes (Suárez-Figueroa et al., 2012).

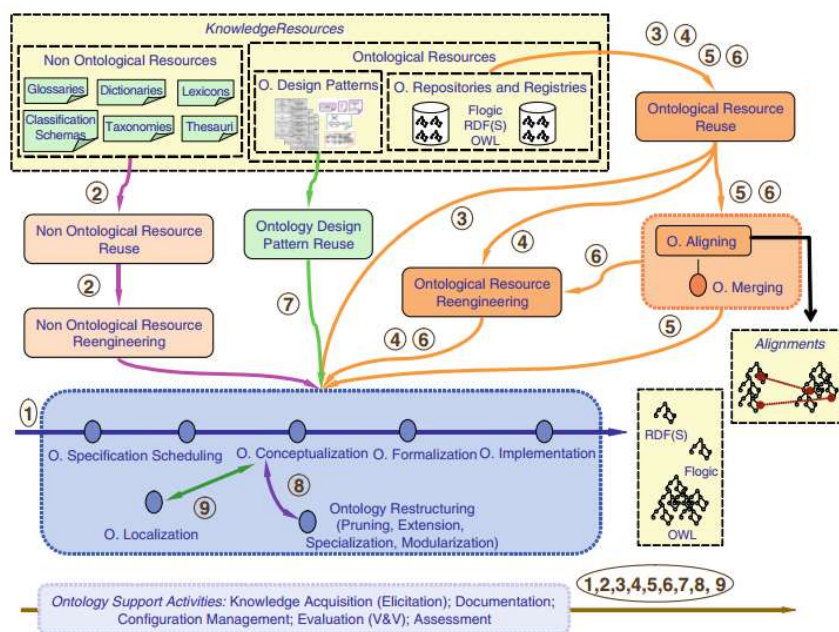


Figure 2. 27. Scenarios for building ontologies (Suárez-Figueroa et al., 2012).

2.5 Tools

The following will introduce several tools for translated ontology in OWL or other machine languages, such as RDF, RDFS, and OIL. It aims to make it machine-readable and processable.

2.5.1 Protégé

Protégé⁴³ software is an ontology editor software written in Java language and developed at Stanford University School of Bioinformatics. It is in open source and used to develop ontologies for the semantic web. Protégé offers an intuitive and easy-to-use graphical user interface and can be easily extended with

⁴³ <https://protege.stanford.edu/>

simple plug-ins (Casellas, 2011). Protégé includes three components: Classes, properties, and individuals (Figure 2.28).

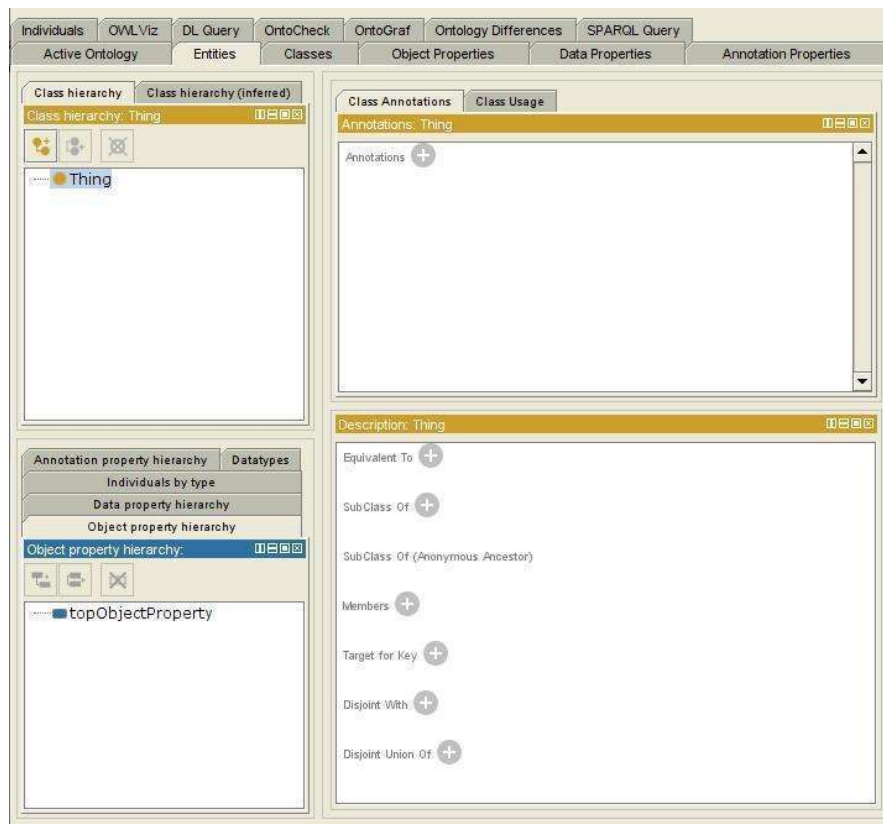


Figure 2. 28. Protégé.

Individual. The individual represents objects in the domain that we are interested in. An important difference between Protégé and OWL is that OWL does not use the Unique Name Assumption (UNA) (Horridge et al., 2004, p. 13). This means that two different names could refer to the same individual. In OWL, it must be explicitly stated that individuals are the same or different from each other (Horridge et al., 2004, p. 13). Figure 2.29 shows a representation of some individuals in some domain



Figure 2. 29. Representation of individuals (Horridge et al., 2004, p. 13).

Properties. Properties include two types: object properties and data properties. In Protégé, objects properties are binary relations on individuals. They are also known as roles in description logics, and relations in UML and other object-oriented notions. In GRAIL and some other formalisms, they are called attributes. Object

properties can have inverses. They can also be either transitive or symmetric. Data properties can be limited to having a single value – i.e., to being functional (Horridge et al., 2004). Figure 2.30 shows a representation of some properties linking some individuals together.

Class. OWL classes are interpreted as sets that contain individuals. They are described using formal (mathematical) descriptions that state precisely the requirements for membership of the class (Horridge et al., 2004). In OWL ontology, classes are a concrete representation of concepts. In Protégé, the first letter of the class name is usually uppercase. A class name is generally singular. Figure 2.31 shows a representation of classes containing individuals.

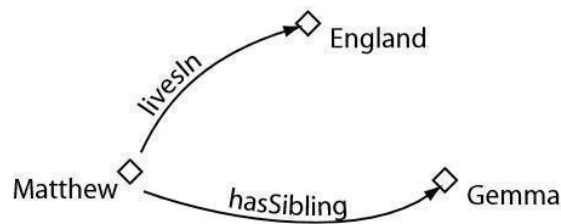


Figure 2. 30. Representation of individuals (Horridge et al., 2004, p. 14).

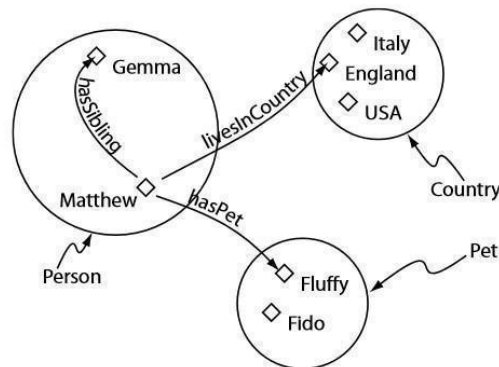


Figure 2. 31. Representation of Classes (Horridge et al., 2004, p. 14).

Reasoner. Protégé provides a reasoner shipped called Fact++, and also allows different OWL reasoners to be plugged. The reasoner offers two services: one of them is to check whether one class is a subclass of another class. Another one is consistency checking (Horridge et al., 2004). A reasoner can compute the inferred ontology class hierarchy by performing the former service on ontology classes. By completing the latter service, based on a class's description (conditions), the reasoner can check whether the class can have many instances. The reasoner is sometimes called classifiers. But classification is not the only service offered by reasoners, it also performs consistency checking. In Protégé, the “manually constructed” class hierarchy is called the *asserted hierarchy* (Horridge et al., 2004). The class hierarchy that is automatically computed by the reasoner is called the *inferred hierarchy*. (Horridge et al., 2004)

Chapter 3. Ontoterminology: Combining Ontology and Terminology

3.1 Definitions

3.1.1 Definition: Name, word, and thing

In the Terminology chapter, we proposed three definitions: name, word (term), and thing. In this chapter, we will present those three types of definitions.

A word definition is also called a term definition, which provides the meaning of a word in the context. As Arnauld and Nicole note, “the explanation of a word’s meaning according to ordinary linguistic practice” (Arnauld & Nicole, 1996). Inside a descriptive terminology, the term definition allows people to take into account the connotative information words acquired through usage. “the incidental ideas the mind connects to the principal ideas of things” (Arnauld & Nicole, 1996), ignored by prescriptive terminology in its standardizing approach (Roche, 2015);

For some specific purpose, a name definition arbitrarily assigns a fixed meaning to a word. It links terms with concepts. The advantage of name definition is that it allows us to select a term as a sign that can grant access to the subject field's knowledge. It helps distinguish terms that designate in usage from those that denote outside discourse (Roche, 2015). Arnauld and Nicole distinguished name definition for a word definition, which explains the meaning of a word in use or etymology.

A thing definition is about the concept itself. Its goal is to understand the nature of objects in a specific knowledge domain. A thing's definition is neither arbitrary nor subjective. The *Dictionnaire de l'Académie française*⁴⁴ defines it in the logical sense, as “*opération de l'esprit par laquelle on détermine l'ensemble des caractères constituant l'essence, la nature d'une chose ; le résultat de cette opération; énonciation de ces caractères dans une proposition*”.

These three definitions are both different and related. Arnauld and Nicole (1996) presented, “word definitions are bound and constrained to represent the truth of usage rather than the truth of things.” Term definition and thing definition remain closely linked. The former is a linguistic explanation, while the latter is by nature of an object. In a specific system, how to connect terms and concepts in a system is a crucial question. Roche proposed a conceptual model named as “*ontoterm*” to unite terms and concepts. The notion of “*ontoterm*” – linking term and concept – makes it possible to group the three types of definition (Roche, 2015) (Figure 2.32).

⁴⁴ <http://atilf.atilf.fr/academie9.htm>

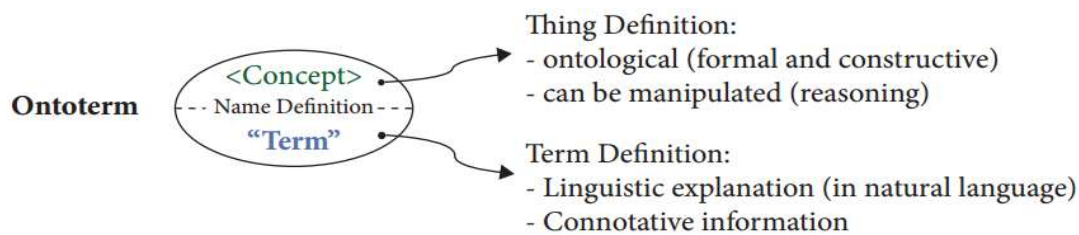


Figure 2. 32. Ontoterm (Roche, 2015).

3.1.2 Definition: Ontoterminology

Recall definitions of Terminology and Ontology are that they are two separate disciplines and have different goals. Then, on some specific application requirements (e.g., IT), ontologies have gradually become the central aspect of terminology work. So, Roche (2007) proposed “*ontoterminology*” the new paradigm to unity ontology and terminology. The definition is “An **ontoterminology** is a terminology whose conceptual system is a formal ontology.”⁴⁵ In the next chapter, we will present ontoterminology, which is the primary framework of this thesis.

3.2 Theory

In terminology, a term is the designation of a concept. So the linguistic relation in the lexical network may be translated into a concept relation, and the lexical network would be translated into a concept network, which sometimes will build an ontology called “text ontology.” Formal ontology directly built by experts does not match the text ontology (Figure 2.33). “The lexicon of languages does not reflect the scientific approach of the world” (Rastier, 2004). “Uttering” and “conceiving” are different activities that mobilize different knowledge, different sign systems, governed by different rules: “Saying is not Modeling” (Roche, 2007).

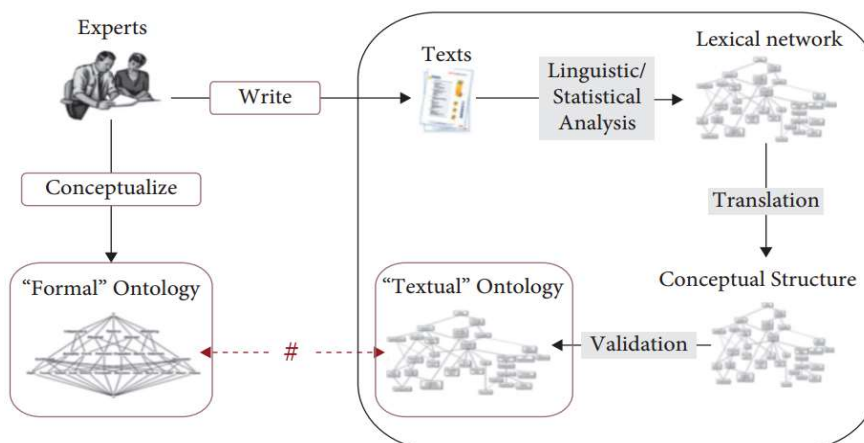


Figure 2. 33. Formal ontology and Textual ontology (Roche, 2007).

⁴⁵ See <http://ontoterminology.com/>

The relationship between the signifier (*signifiant*) and signified (*signifié*) in linguistics. This kind of relationship is like the relation between terms and concepts in terminology. The concept is the mental representation of individual objects, while the term is a designation of concepts. A signified (*signifié*) must, in other words, not be identified with a concept. Similarly, a term – a specialized lexical unit – should not be identified with a concept’s name, an identifier⁴⁶ of a formal system (Roche, 2015). There is a double semiotic triangle to explain the relationship between different definitions of these factors (Figure 2.34).

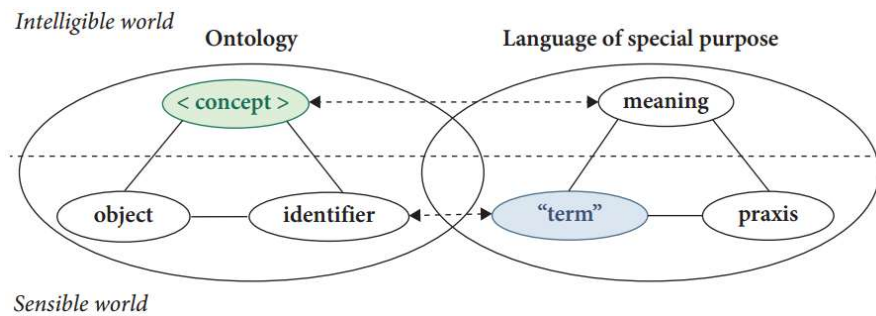


Figure 2. 34. A double semiotic triangle (Roche, 2012).

Figure 2.34 shows that terminology is divided into two dimensions: conceptual dimension (ontology) and linguistic dimension (the language of special-purpose (LSP)). The linguistic dimension is separated from the conceptual dimension. The term (signifier) and meaning (signified) about the linguistic and natural languages are separated from the identifier and concept. Furthermore, the definition of terms (written in natural language) is separated from the definition of concepts (written in formal language).

Let us recall the definition of ontoterminology: “An **ontoterminology** is a terminology whose conceptual system is a formal ontology.” First, the ontoterminology belongs to the terminology discipline; Second, the ontoterminology is based on the double dimension of terminology and unifies the double dimension into a paradigm; Third, the ontoterminology focuses on the conceptualization and formal expression (ontology) of terms. It provides an approach to building the concept of terms based on the epistemological principles. As Roche notes, “concept system is a formal ontology relying on epistemological principles' ' (Roche, 2012a).

3.3 Methodology: Term-guided ontology building

Concepts and essential characteristics are two vital aspects of the ontoterminology approach. The concept is composed of essential characteristics. The following chapter will present them in detail.

3.3.1 Concept and essential characteristic

For terminology, concepts are considered mental representations of objects within a specific context or field (ISO 704, 2009). Concepts are not to be confused with abstract or imagined objects (i.e., concrete, abstract, or imagined objects in a given context are observed and conceptualized mentally, and then a designation is

⁴⁶ Not to be reduced – even though from a theoretical point of view that does happen – to an arbitrary symbol (e.g. a number), as in certain terminological environments. Naming concepts in a formal system requires the terminologist’s and the experts’ undivided attention. It is constructed in such a way that, simply by reading it, one understands the place the concept occupies inside the notional system.

attributed to the concept rather than the objects themselves). For the ISO 704 International Standard, the link between an object and its designation (term) or definition is made through the concept, a higher level of abstraction (ISO 704, 2009) (Figure 2.35). On the representation level, a concept is specified by a definition and is referred to by a name (term).

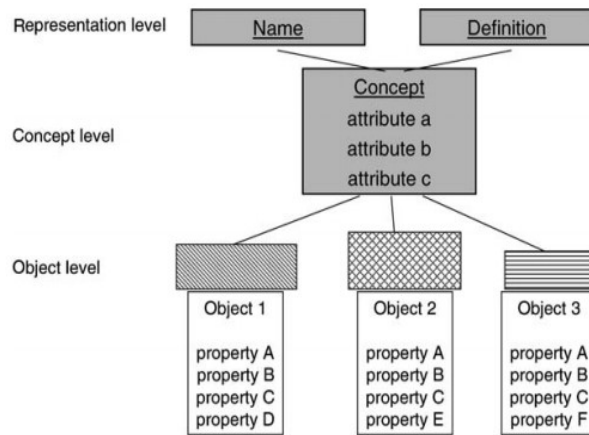


Figure 2. 35. Object level, concept level, and representation level (Stumme, 2009).

On the concept level, objects under discussion constitute the extension of concepts, while their shared properties constitute concepts' intension (Stumme, 2009). ISO 1087-1 defines the concept as a “unit of knowledge created by a unique combination of characteristics.” In turn, Characteristics are defined as "abstraction of a property of one or more objects." ISO 1087-1 further divides characteristics into essential characteristics and non-essential characteristics. For practical purposes, Characteristics are considered essential if they are indispensable for understanding the concept in a particular field of knowledge; the absence of an essential characteristic fundamentally changes concepts. In description logics, essential characteristics correspond to rigid predicates (Guarino & Guizzardi, 2006). In the OntoClean method, an entity's property is *essential* to that entity if it *must* be true of it in every possible world, i.e., if it *necessarily holds* for that entity (Guarino & Welty, 2004). The essential characteristic corresponds to the essential property in the OntoClean method. Additional to essential characteristics, there is another important characteristic: a descriptive characteristic which does not constitute concepts, unlikely essential characteristics. However, the descriptive characteristic plays a vital role in describing the object. The descriptive characteristic could be these properties, such as height, color, length, and weight.

Concept formation provides the means for recognizing objects and for grouping them into meaningful units in a particular field (ISO 704, 2009). Objects perceived as sharing the same properties are grouped into units. Once similar objects (or occasionally a single object) are viewed as a meaningful unit of thought within a branch of human knowledge, properties of objects or common to a set of objects are abstracted as characteristics, which are combined as a set in the formation of a concept (ISO 704, 2009). A concept is a set of essential characteristics, which is stable enough to be denoted by a term. We also could consider the concept as an *identity* that refers to the problem of being able to recognize individual entities in the world as *being* the same (or different) (Guarino & Welty, 2004).

3.3.2 Term-guided method for defining concept

From the ISO point of view on terminology, a concept is defined as a unique combination of essential characteristics (ISO 1087-1, 2019). Nevertheless, not any combination of essential characteristics defines a meaningful concept from the expert point of view. Indeed, for the experts, concepts of interest are those that are named in a natural language. It means that a concept is a set of essential characteristics that is stable enough to be named in a given language. We can notice that some concepts, without any designation in natural language, can be introduced for organizational purposes. Hence, terms can be considered as guidelines for identifying concepts to be defined. For example, the Chinese term “椅子” (“chair” in English) denotes the following set of essential characteristics {/seat/, /one person/, /without arms/, /with back/, /with foot/}. This unique combination of essential characteristics defines a concept whose name (identifier) in the conceptual system is built from the names of essential characteristics (the concept name is built in such a way to promote transparency of the idea the concept conveys). Based on this formal definition of concepts, we can propose the following definition of the term “chair” written in natural language in compliance with the Aristotelian definition in genus and specific differences: “Seat for one person with back, foot, and without arms”.

3.3.3 Ontoterminology: the example of seats

1). Identifying terms. Terms are the starting point of the ontology building process. We need to identify terms and objects denoted by terms. Terms could be either extracted from books, databases, and the internet or of course, given by experts. For our example, let us consider the terms “chair” (“chaise”), “armchair” (“fauteuil”), “stool” (“tabouret”), “couch” (“canapé”), and “bench” (“banc”) in English and French respectively.

2). Identifying essential characteristics. This step has to be achieved before defining concepts. Domain experts and epistemological principles play an essential role in this step. For example, there are many different seats in the domain of seats, such as chair, armchair, stool, couch, and bench. When we face a seating object, we need to understand it. Then select a proper language to represent it. Identifying essential characteristics also insists on epistemological principles and experts’ knowledge. From a functional point of view, when we face seat objects, it could include essential characteristics: /one person/ and /several persons/. From a structural point of view, we may partition the seat into three components: arm, back, and leg. The differences between arms are with arm, and without arm, so essential characteristics are /with arm/ and /without arm/. Essential characteristics are /with back/ and /without back/ for the back component. The essential characteristics are /with leg/ and /without leg/ for leg component. Let us note that essential characteristics of the same axis of analysis are disjointed. They could not appear in a concept at the same time because it is not logical. For example, a seat could not satisfy the two characteristics of /with arms/ and /without arms/ at the same time. Table 1 shows all the essential characteristics of the seats. Descriptive characteristics include color and weight, which could not change the chair's nature (concept).

Table 1. Essential characteristics of seats.

Axis of analysis:	Number of person		Arms		Back		Foot	
Essential characteristic:	/one person/	/several persons/	/with arms/	/without arms/	/with back/	/without back/	/with foot/	/without foot/

3). Term guided to construct concepts based on essential characteristics. Let us recall the concept definition that is a “unit of knowledge created by a unique combination of *characteristics*” (ISO 1087-1, 2019). Therefore, to define a concept, we need to combine essential characteristics. Table 1 shows that there are eight essential characteristics organized into four axes of analysis. If we combine all of them, the complete developed Porphyry tree owns 2^4 (16) terminal concepts, i.e., concepts which can be instantiated. But not all these terminal concepts are relevant in our seat example, e.g., there is no seat with arms and without back since there is no name for denoting such objects. Of course, it does not mean that it is impossible to build such seats, but in our example, we are interested only in seats designating by one of the previously identified terms. Following terms is therefore a very useful means for building concepts. For example, in the seat domain, there are five terms: “chair”, “armchair”, “stool”, “couch”, and “bench”. We only need to construct five concepts. For example, the term “chair” designates the concept <Seat for one person without arms with back with foot> defined by the unique combination of essential characteristics /for one person/, /without arms/, /with back/ and /with foot/. All concepts of seats are shown in table2

Table 2. Concept of all kinds of seats.

Term	Concept	Number of person		Arms		Back		Foot	
		One person	Several persons	With arms	Without arms	With back	Without back	With foot	Without foot
“chair”	<Seat one person without arms with back with foot>	×			×	×		×	
“armchair”	<Seat one person with arms with back with foot>	×		×		×		×	
“stool”	<Seat one person without arms without back with foot>	×			×		×	×	
“couch”	<Seat several persons with arms with back with foot>		×	×		×		×	
“bench”	<Seat several persons without arms without back with foot>		×		×		×	×	

4). Building ontology by tools. Step 3 focuses on constructing concepts based on essential characteristics. The main work of this step is to build ontology based on concepts by tools. For the ontoterminology approach, there is an assist tool called Tedi to build an ontology. Chapter 3.4 will present the tool to build an ontology.

3.4 Tool

Tedi, for ontoTerminology EDItor, has been developed by the Condillac research group of University Savoie Mont-Blanc (Christophe Roche). A software environment dedicated to building multilingual ontoterminology (an ontoterminology is a terminology whose conceptual system is a formal ontology)⁴⁷. Tedi allows users to define formal ontologies and set of terms in different languages independently of each other. The different sets of terms are linked through the shared ontology⁴⁸, allowing to calculate equivalents automatically. Tedi enables users to export ontologies in different exchange formats (RDF/OWL, HTML, CSV). The ontoterminology includes two dimensions: the linguistic dimension and the conceptual dimension. Tedi provides a set of editors dedicated to the conceptual dimension (concept editor, object editor, characteristic editor, relation editor) and editors dedicated to the linguistic dimension (term editor, proper name editor, and feature editor).

Concept editor. Epistemological and logical principles play an essential role in ontoterminology. Under epistemological and logical principles guiding, concept editor is dedicated to ontology building and provides a set of features of the definition of essential characteristics (axes of analysis), descriptive characteristics (attributes), concepts (Figure 2.36), and relations (Figure 2.37)⁴⁹.

⁴⁷ <http://ontoterminology.com/tedi>

⁴⁸ <http://ontoterminology.com/tedi>

⁴⁹ <http://ontoterminology.com/concept-editor>

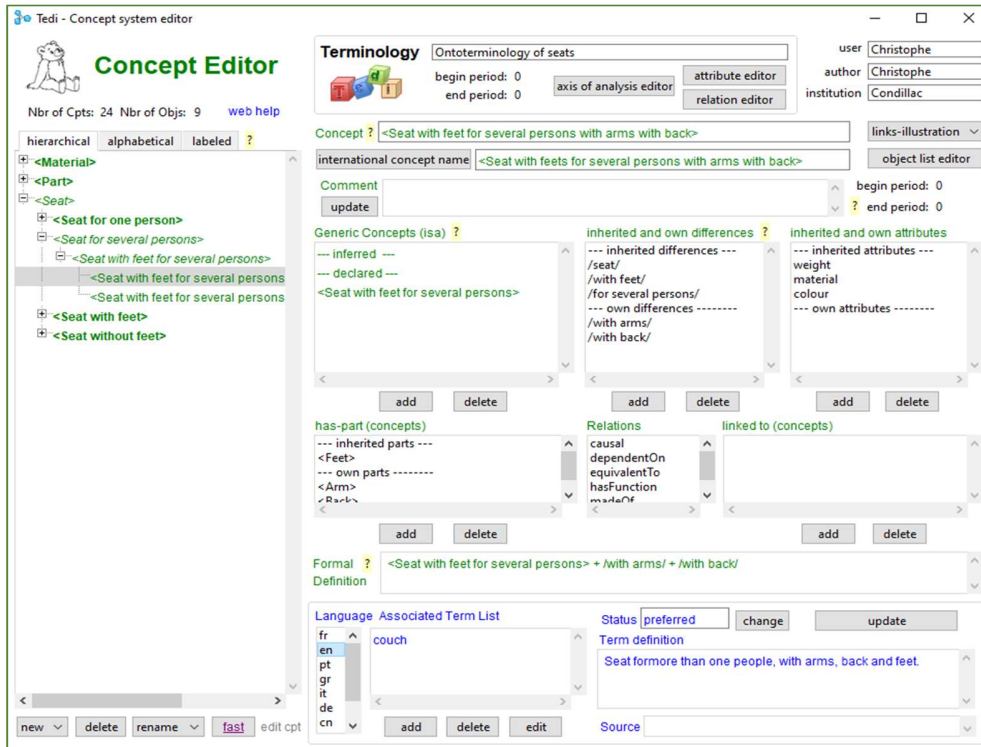


Figure 2. 36. Concept editor of Tedi.

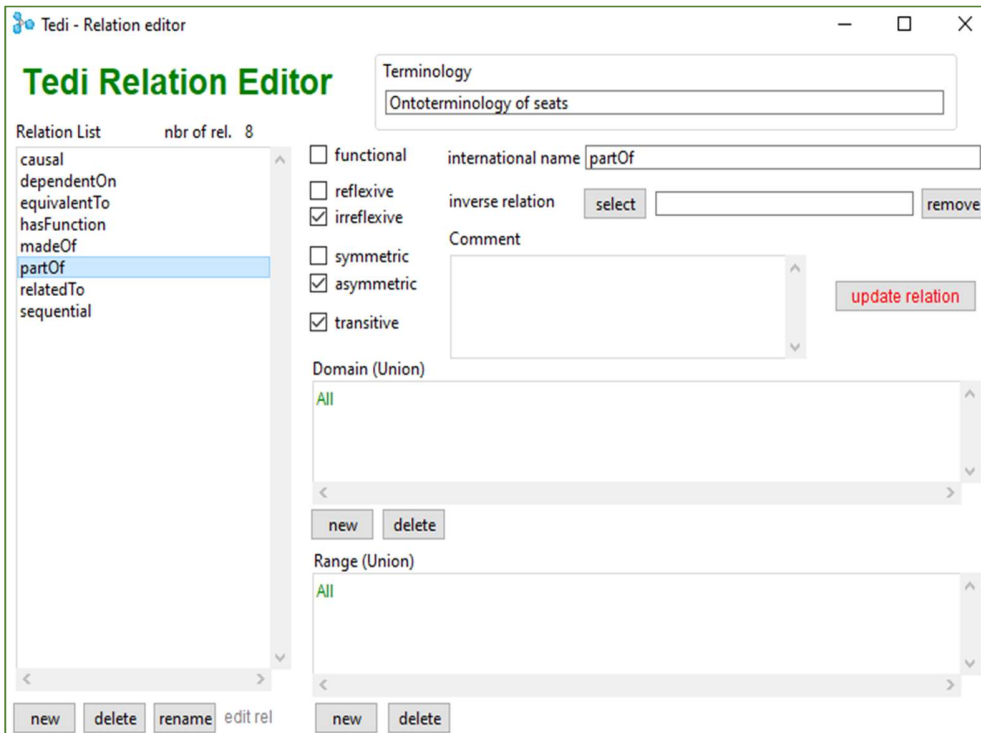


Figure 2. 37. Relation editor.

Term editor⁵⁰. The term editor is dedicated to term definition into different languages sharing the same ontology (Figure 2.38). For every language, the Term editor provides a set of features for the definition of the term itself, including the definition in natural language, contexts, and notes, term status, and PoS. It allows users to specify concept(s) denoted by terms, i.e., The meaning of the term from a terminological point of view. Meanwhile, as different terms share the same ontology, equivalent terms of different languages could be automatically identified.

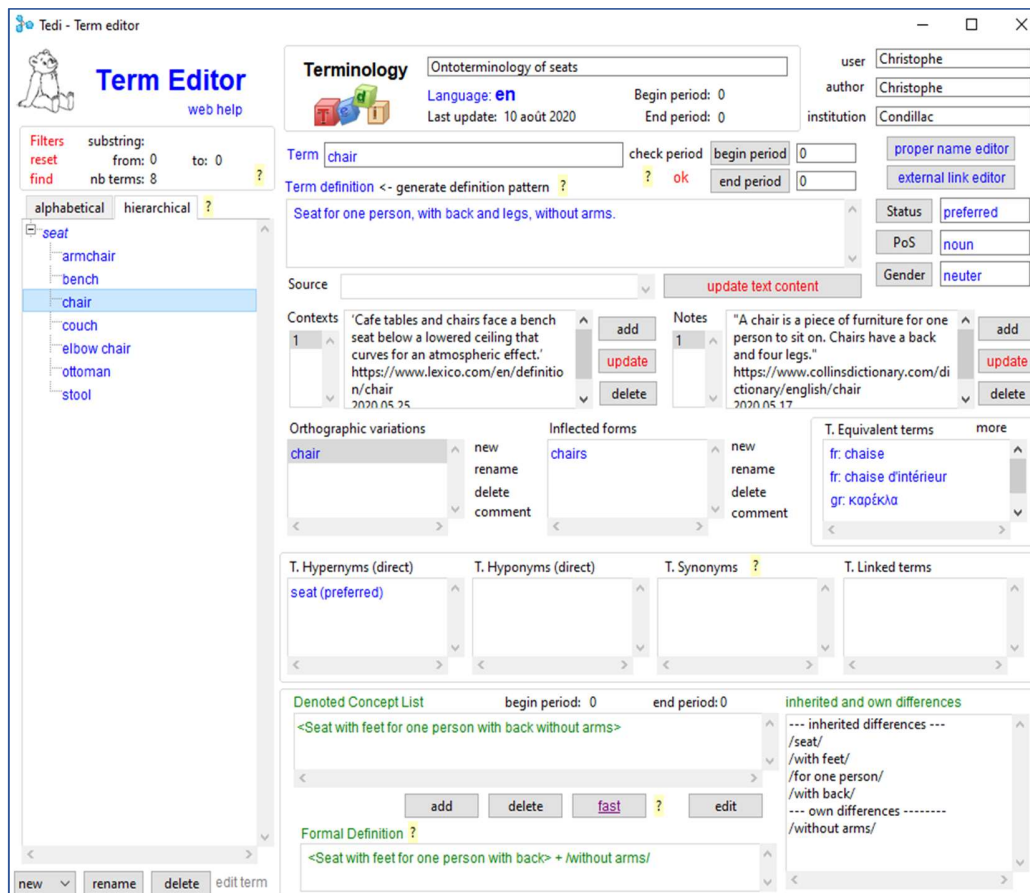


Figure 2. 38. Term editor of Tedi.

Exchange format. Tedi could export different formats, such as CSV, HTML, RDF/OWL, JSON, and OTE (a complete definition of the ontoterminology in an XML format). For example, it is exported in HTML formal in French (Figure 2.39).

⁵⁰ <http://ontoterminology.com/term-editor>

Tedi Onto-Dictionary on "Ontoterminology of seats" (en)

Date: 29 août 2020 - Time: 19:12:48 - Version: 2.1 - www.ontoterminology.com/tedi

search:

- armchair
- bench
- chair**
- couch
- elbow chair
- ottoman
- seat
- stool

chair


Definition: Seat for one person, with back and legs, without arms.
Status: preferred
Context(s):
 1) 'Cafe tables and chairs face a bench seat below a lowered ceiling that curves for an atmospheric effect.'
<https://www.lexico.com/en/definition/chair>
 2020 05 25
Note(s):
 1) "A chair is a piece of furniture for one person to sit on. Chairs have a back and four legs."
<https://www.collinsdictionary.com/dictionary/english/chair>
 2020 05 17

Equivalent(s):
 - fr: chaise (preferred)
 - fr: chaise d'intérieur (alternative)
 - gr: καρέκλα (preferred)

Concept: <Seat with feet for one person with back without arms>
essential characteristic(s): /seat/, /with feet/, /for one person/, /with back/, /without arms/,
a kind of: <Seat with feet for one person with back>,
linked to: <Back>, <Feet>,

rdfs:seeAlso <https://fr.wikipedia.org/wiki/Chaise>
skos:exactMatch <http://vocab.getty.edu/page/aat/300037772>

Web reference: [Le grand salon de l'impératrice au château de Fontainebleau du temps de l'impératrice Eugénie](#)
Illustration: Chaises estampillées Georges Jacob, grand cabinet du Dauphin, château de Versailles.



Objects of this type: 2

Figure 2. 39. e-Dictionary of Seats.

3.5 Protégé vs. Tedi

(Desprès et al. 2019) compared Protégé and Tedi. The example used in this study also comes from the Digital Humanities. Its purpose is to build the ontology and terminology of vases of Ancient Greece. Protégé and Tedi differ on many points that could be summarized by saying that the former is as universal as the latter is specific. Indeed, Protégé is a free, open-source software, the most widely used ontology editor, supported by a large community of users (Musen, 2015). It relies on the Description Logic for the theory of concept and on the W3C recommendations for representation languages. Protégé has a universal aim in the sense that it is not limited to the construction of ontologies for terminological purposes. On the opposite side, Tedi has not a universal purpose. It is a recent software, not in open source. Its first version dates from 2018 when Protégé dates from 1980. It is intended for experts to build ontoterminologies in accordance with the ISO principles on Terminology. Tedi relies on a theory of concept close to the understanding of domain experts. It also implements a methodology that guides experts in building ontoterminologies. Desprès et al. 2019 conclude by stating that the choice between Protégé and Tedi is made mainly based on the objectives of the project and the theory of concept.

Chapter 4. Semantic Web for Cultural Heritage

4.1 Cultural Heritage

4.1.1 Definition

“Digital humanities” is developed from “humanities computing”, which is considered to be a supplementary study of humanities issues by introducing technologies and methods such as computers and statistics (Chen, 2014). Cultural heritage is an important branch of digital humanities research. In the field of cultural heritage, the term “cultural heritage” supersedes “cultural property”. UNESCO used the term “cultural property”, which is defined as “movable cultural property shall be taken to mean all movable objects which are the expression and testimony of human creation or the evolution of nature and which are of archaeological, historical, artistic, scientific or technical value and interest” (UNESCO, 1978). Property is a fundamental legal concept around which critical political and philosophical theories have developed (Prott & O’Keefe, 1992). However, the “property” could not cover all evidence of human life that needs to be preserved. For example, the immovable objects include buildings, landscapes, rivers, and lakes. “Property” could not embody the notion of inheritance and hand. From the perspective of the law, the fundamental policy behind property law has been seen as protecting the rights of the possessor, whereas the fundamental policy behind cultural heritage law is the protection of the heritage for the enjoyment of present and later generations (Prott & O’Keefe, 1992). Therefore, “heritage” is better than “property”. “Cultural heritage” has now become the state-of-art term in international law since it can encompass this much broader range of possible elements, including the intangibles mentioned above (Blake, 2000; Prott & O’Keefe, 1992).

Cultural heritage is the manifestation of human life, which reflects a particular view of life and history. It is essential to understand the concepts of “culture” and “heritage” for understanding the concept of cultural heritage. From the literature perspective, many authors define “culture” as “Culture is an umbrella term which encompasses the social behavior and norms found in human societies, as well as the knowledge, beliefs, arts, laws, customs, capabilities and habits of the individuals in these groups”⁵¹. “Culture is the product of the human activity, particularly those things that are socially transmitted, including beliefs, practices, objects, etc.” (Appiah, 1994, pp. 111–112; Scheffler, 2009). “Culture is often treated as a “good” thing in the context of the cultural heritage literature, even though some cultural practices are subject to severe moral objections” (Brown, 2005; Okin, 1999).

“Heritage” usually refers to something inherited from the past. Heritage includes different forms of cultural capital, “which embodies the community’s value of its social, historical, or cultural dimension” (Throsby, 1997, p. 15). From a cultural economics perspective, Chastel states that “heritage includes a large range of goods, whose definition changes over time and space and depends on the variety of dimensions (symbolic, cultural, national identity-oriented, social and suchlike) included in the concept” (Babelon & Chastel, 1980; Benhamou, 2020). Peacock also has the same opinion on heritage definition: “an intangible service increasing the utility of consumers, in which historic buildings and artifacts are inputs” (Benhamou, 2020,

⁵¹ <https://en.wikipedia.org/wiki/Culture>

p. 256; Peacock, 1994). However, heritage is best understood as a process of interpretation that is ongoing. As Smith noted, “Heritage... is a cultural process that engages with acts of remembering that work to create ways to understand and engage with the present, and the sites themselves are cultural tools that can facilitate but are not necessarily vital for this process.” (Matthes, 2018; L. Smith, 2006, p. 44).

The concept of “cultural heritage” is popular with historians, archaeologists, anthropologists, and other researchers. “Cultural heritage” was first addressed in international law in 1907. ICOMOS defines “cultural heritage” as “an expression of the ways of living developed by a community and passed on from generation to generation, including customs, practices, places, objects, artistic expressions, and values” (ICOMOS, 2002).

4.1.2 Categories of cultural heritage

Binford (1964) presented four basic units for archaeological data: *artifacts*, *ecofacts*, *cultural features*, and *sites*. Kipfer considered archaeological evidence into *artifacts*, *ecofacts*, *features*, and *structures* (Kipfer, 2000, p. 30). According to Binford, artifacts “are discrete entities, the formal characteristics of which are partially the result of cultural activity or events” (Binford, 1964, p. 430). Artifacts are culturally removable that moved from their place of discovery without affecting their formal characteristics.

According to UNESCO⁵² and ICOMOS⁵³, the category of cultural heritage is tangible heritage and intangible heritage (i.e., Oral traditions, performing arts, rituals). The tangible cultural heritage includes movable cultural heritage (i.e., Paintings, sculptures, coins, manuscripts.), immovable cultural heritage (i.e., Monuments, archaeological sites.), and underwater cultural heritage (i.e., Shipwrecks, underwater ruins, and cities)⁵⁴. Figure 2.40 shows the categories of cultural heritage.

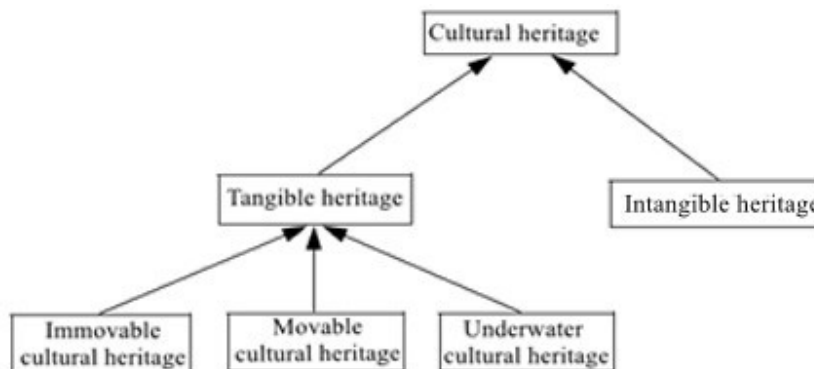


Figure 2. 40. The categories of cultural heritage.

Ceramic is a vital kind of movable cultural heritage. From the archaeological data perspective, ceramics belong to artifacts. Ceramics are ubiquitous cultural artifacts in human cultures and invaluable information

⁵² United Nations Educational, Scientific and Cultural Organization

⁵³ International Council on Monuments and Sites

⁵⁴ <http://www.unesco.org/new/en/culture/themes/illicit-trafficking-of-cultural-property/unesco-database-of-national-cultural-heritage-laws/frequently-asked-questions/definition-of-the-cultural-heritage/>

sources on the societies that produced and used them. Their conservation is the significance of the presentation of cultural memory. Ceramics includes many types, such as potteries, porcelains, and glasses. In cultural heritage, the definition of ceramic is restricted to crystalline artifacts and works of art made of clay—composed usually of the silica-aluminum mineral kaolinite or iron-containing illite accompanied by various admixtures—and fired under various conditions, conferring the requested properties (Varella, 2012). Ceramics also are important research artifacts in this thesis.

4.2 Semantic Web

4.2.1 From Document Web to Web of data

Web 2.0 is the web of documents: it links documents through hyperlinks (Figure 2.41). This kind of Web limits computers to understand and combine information on web data. “Data should be provided in such a way that not only humans can read it; computers should also be able to manipulate and recombine the information meaningfully” (Berners-Lee et al., 2001). Therefore, W3C promotes the transformation from the Document Web to the Web of data (Figure 2.42). The Web of data's goal is to enable computers to do more useful work and develop systems that can support trusted interactions over the network⁵⁵. The term “Semantic Web” refers to the W3C’s vision of the Web of linked data and is a Web of data. W3C defines “Semantic Web”: “The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries⁵⁶”.

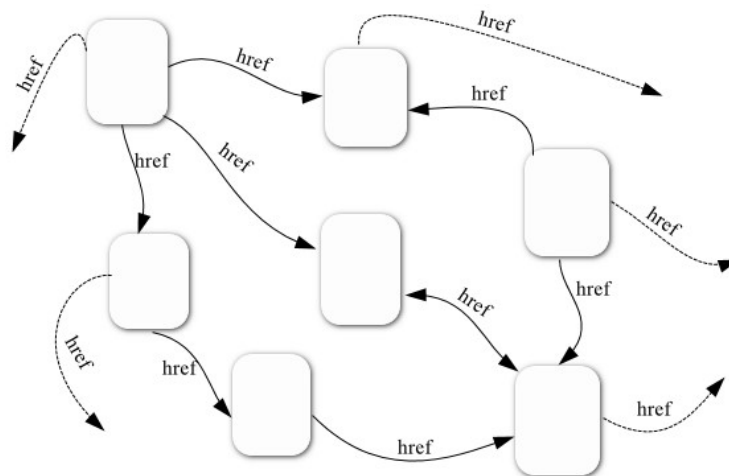


Figure 2. 41. Document Web.

⁵⁵ <https://www.w3.org/standards/semanticweb/>

⁵⁶ <https://www.w3.org/2001/sw/>

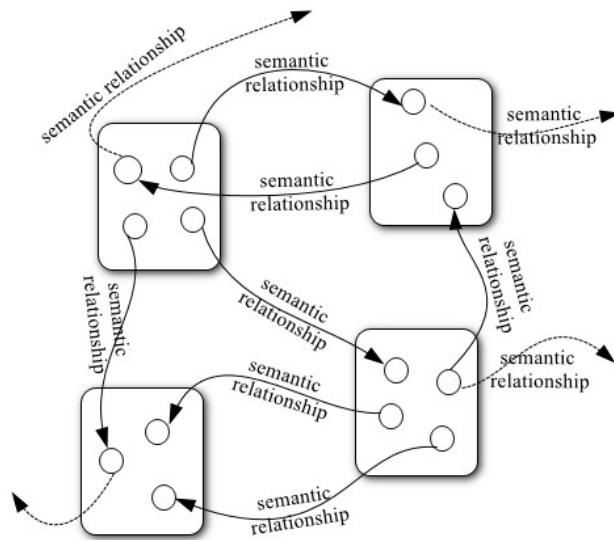


Figure 2.42. Web of data.

4.2.2 Semantic Web stack

Semantic Web is composed of many technologies representing the building block of stake, which evolved from the proposal in 2000 to a widely used slide in 2001 and the last report in 2005 (Figure 2.43). The definitive version is 2005, which shows the stake's base is a **URI** and **Unicode** that is the standard text encoding format.

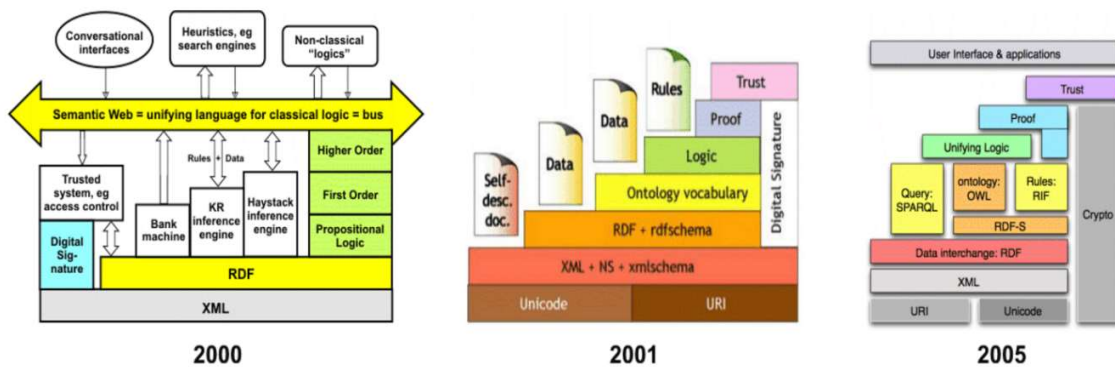


Figure 2.43. Evolution of Semantic Web from 2000 to 2005⁵⁷.

XML allows syntactic interoperability and partial structural interoperability.

RDF, **RDFS**, and **OWL**, as languages, have been introduced in the languages section of the chapter Ontology.

⁵⁷ <http://www.jfsowa.com/ikl/>

SPARQL (Simple Protocol and RDF Query language) is a query language for RDF (and then also for OWL) and a protocol that enables this kind of request in a Web environment⁵⁸. It can retrieve and manipulate data stored in RDF and is one of the Semantic Web's critical technologies. SPARQL constructs are like SQL, both in syntax and meaning. For example, Select, From, and Where clauses. It allows us to express queries across diverse data sources, whether the data is stored locally or other data sources as RDF⁵⁹. SPARQL endpoints can receive the SPARQL query and send the results. It is important to stress that the SPARQL endpoint keeps the incoming query request and internal application data distinct. This way, it is possible to use a preferred technology (such as an RDBMS) for internal data management, provided a translation component between SPARQL and the internal query language (e.g., SQL) is defined (Mantegari, 2010, p. 44).

RIF is a semantic Interchange of rules, which could be useful for automated reasoning and expressed in different languages.

Unifying logic identifies the need for a logic upon which the mediation between the information and knowledge representation of the lower levels and the issues connected to its dissemination to users (upper levels) is built (Mantegari, 2010, p. 44).

Proof block presents the problem related to building the truth of statements.

Trust block shows the different levels of trust in data retrieved from the web by a user.

Crypto identifies that the information shared could get from affordable resources.

Finally, the user could build applications or interfaces based on the information shared in the Semantic Web.

4.2.3 Linked Open Data

4.2.3.1 Linked data

Linked data is “a set of design principles for sharing machine-readable data on the Web for use by public administrations, businesses, and citizens.”⁶⁰ It builds on standard web technologies, such as HTTP, RDF, and URIs. Hyperlinks link documents into a single global information space in classic Web. Likely, linked data enables connecting items in different data sources into an available global data space. In July 2006, Berners-Lee presented principles of designing linked data initially:

1. *Use URIs as names for things;*
2. *Use HTTP URIs so those names can be looked up (aka dereferencing);*
3. *Return useful information upon lookup of those URIs (esp. RDF);*
4. *Include links by using URIs, which dereference to remote documents.* (Berners-Lee, 2006)

The first principle is essential to build linked data. It is useful for retrieval by using HTTP URIs to identify real-world entities and their relations, reflecting the second principle. There are two methods to make URIs

⁵⁸ <https://www.w3.org/TR/rdf-sparql-query/>

⁵⁹ <https://rebeccabilbro.github.io/sparql-from-python/>

⁶⁰ https://www.europeandataportal.eu/sites/default/files/d2.1.2_training_module_1.2_introduction_to_linked_data_en_edp.pdf

dereference: 303 URIs and Hash URIs. For the third principle, it needs to provide a standardized content format (RDF) for different applications. The fourth principle is to set RDF links to point to other data sources to interconnect data space and discover additional data sources in applications.

4.2.3.2 Publishing Linked Data

Usually, there are five steps to publish linked data.

Step 1: Understand the principles. The principle refers to the laws of designing linked data that have been introduced in the previous chapter.

Step 2: Understand the data. In this step, the main work is to understand data objects in linked data, such as people, location, pictures, books, concepts, and films. Selecting vocabularies describe data.

Step 3: Selecting URIs for things in data. It is to choose suitable URIs to name things in data. The vital principle of choosing URIs is to decide URIs' Hash (e.g., <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase>) or Slash (e.g., <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl/ArrowVase>).

Step 4: Setup infrastructure. Figure 2.44 shows the infrastructure of publishing linked data. When the user sends a request, the service determines to return HTML or RDF according to the content negotiation. Other languages, such as Java, could also replace PHP.

Step 5: Linked other data sets. The data may link to other data sources, which have been published on the web, such as DBpedia and Geonames, to discover more information. The predictions for connecting may be *owl:sameAs*, *foaf:homepage*, and *rdfs:seeAlso*.

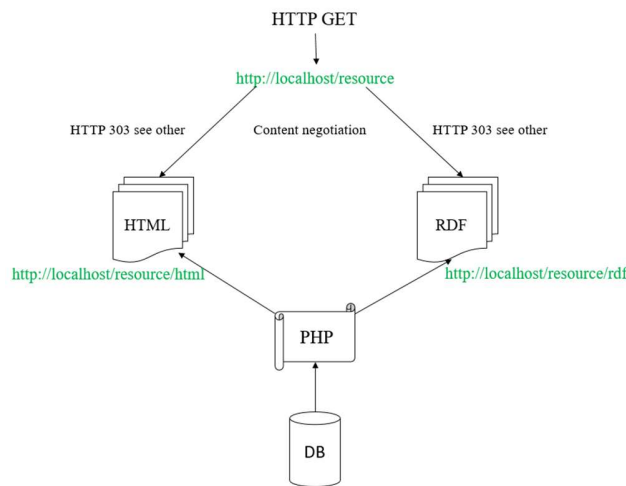


Figure 2. 44. The infrastructure of publishing linked data.

4.2.3.3 Linked Open Data

Open Data is “Open Data is data that can be freely used, reused and redistributed by anyone – subject only, at most, to the requirement to attribute and share alike.”⁶¹ Open Data differs from linked data. For Open Data, the data could be published and be freely used under an open license without linking other data sets. However, for linked data, data should link to other data sources using open standards. With the growth in Open Data published on the web, W3C announced a new project called “Linking Open Data” to promote linked data principles. The goal of the Linking Open Data project is twofold: (i) to introduce the benefits of RDF and Semantic Web technologies to the Open Data movement, and (ii) to bootstrap the Web of Data by creating, publishing, and interlinking RDF exports from these open datasets (Heath & Bizer, 2011). Tim Berners-Lee gives the most explicit definition of Linked Open Data that is “Linked Open Data (LOD) is Linked Data which is released under an open license, which does not impede its reuse for free.”⁶² 5-star open data principles, proposed by Tim Berners-Lee,⁶³ are vital to linking open data:

- ★ Make your stuff available on the Web (whatever format);
- ★★ Make it available as structured data;
- ★★★ Use non-proprietary formats (e.g., CSV instead of Excel);
- ★★★★ Use URIs to denote things so that people can point at your stuff;
- ★★★★★ Link your data to other data to provide context.

Linked open data has benefits for developers, citizens, and businesses. 1) Linked open data could reduce redundancy by establishing upon and others work to make resources as efficiently; 2) linked open data increases information quality through using the standardization of metadata and data formats; 3) linked open data creates added value through connecting directly to other data; 4) Linked open data increases transparency⁶⁴. Figure 2.45 shows the LOD Cloud diagram, which has contained 1239 datasets with 16147 links (as of March 2019)⁶⁵

⁶¹ <http://opendefinition.org/>

⁶² https://en.wikipedia.org/wiki/Linked_data

⁶³ <https://5stardata.info/en/>

⁶⁴ <https://landportal.org/developers/what-is-linked-open-data>

⁶⁵ <https://lod-cloud.net/>

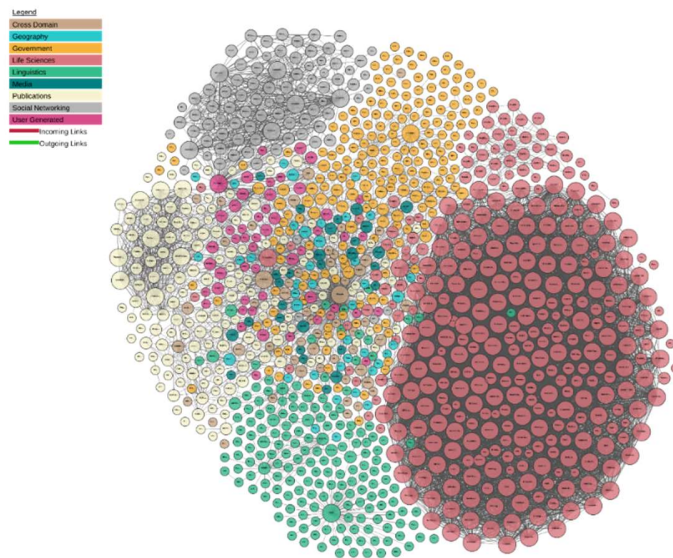


Figure 2. 45. Linked Open Data Cloud.

4.2.3.4 Knowledge Graph

In 2002, Google proposed the term “Knowledge Graph” initially in a blog title “*Introducing the Knowledge Graph: things, not strings.*”⁶⁶ A knowledge graph is an entity-centric view of linked data. So, its foundations and architecture are similar to linked data. An information system based on the knowledge graph often includes three components: construction, storage, and consumption. Most technologies are from Knowledge Representation, Databases, Ontologies, and Semantic Web for the construction and storage. The knowledge graph could be accessed and analyzed by Sparql, search engine, and interfaces.

In many articles, these terms “RDF dataset”, “Linked Data” and “Knowledge Graph” are often presented in the similarity. These three concepts are different. RDF datasets are data collections that the data is stored in RDF format. Linked Data refers to interlink multiple RDF datasets that are distributed independently. Knowledge Graph is a structured data set compatible with the RDF data model and has an (OWL) ontology as its schema (Pan et al., 2017, p. 51). A knowledge graph is not necessarily linked to external knowledge graphs (Pan et al., 2017, p. 51). Table 3 shows the comparison of the RDF dataset, Linked Data, and Knowledge Graph.

Table 3. RDF dataset, Linked Data, and Knowledge graph.

Characteristic	RDF datasets	Linked data	Knowledge graph
Human readability	Not necessary	Not necessary	Yes
Machine readability	Yes	Yes	Yes

⁶⁶ <https://googleblog.blogspot.com/2012/05/introducing-knowledge-graph-things-not.html>

Inter-dataset linkage	Limited	Yes	Yes
Data distribution	Not	Yes	Not necessary
Data integration	Not necessary	Not necessary	Yes
Data consistency	Not necessary	Not necessary	Yes
High quality	Not necessary	Not necessary	Yes
Reliability	Not necessary	Not necessary	Yes

4.2.3.5 Vocabularies & Ontologies

Ontologies are a critical element of Linked Open Data and Knowledge graphs as they need schemas. To speed up the knowledge graph development and reduce the heterogeneity of data, reusing existing vocabularies is essential. There are some standard vocabularies introduced in the following. RDF and OWL are also a kind of standard vocabularies and have been presented in previous chapters.

Friend-of-a-Friend (FOAF)

It is a machine-readable ontology describing persons, their activities, and their relations to other people and objects⁶⁷. Anyone could use FOAF to express themselves. Main FOAF terms could be grouped into three categories.

Core: These classes and properties could describe people and social groups (Dragoni, Poveda-Villalón, et al., 2016, p. 101). They could explain the necessary information about people in the present day, cultural heritage, and histories, such as agent, person, name, title, image, and age.

Social Web: These terms are used to describe internet accounts, address books, and other web activities.

Linked Data utilities: It attempts to use the Web to integrate factual information with information in human-oriented documents and information still in people's heads. FOAF includes a few "demonstration" terms that serve a mostly educational purpose, alongside a few technical utility terms (e.g., Focus, LabelProperty) that support broader information-linking efforts⁶⁸.

Simple Knowledge Organization System (SKOS)

It is a data model for sharing and linking knowledge organization systems on the Web⁶⁹. The SKOS W3C standard's primary goal is to provide a lightweight ontology format in RDF for representing vocabularies, such as legacy thesauri and classifications (Isaac & Summers, 2009; Pastor-Sánchez et al., 2009). The model is compatible with RDFs and the OWL standard for representing ontologies. SKOS could capture much of the semantics of existing museums and other memory institutions thesauri. SKOS data model views a

⁶⁷ [https://en.wikipedia.org/wiki/FOAF_\(ontology\)](https://en.wikipedia.org/wiki/FOAF_(ontology))

⁶⁸ <http://xmlns.com/foaf/spec/>

⁶⁹ <https://www.w3.org/TR/skos-reference/#notes>

knowledge organization system as a concept scheme comprising a set of concepts that could be labeled with any number of lexical strings⁷⁰. Moreover, SKOS concepts could link to other SKOS concepts by semantic relationships and could be grouped into collections.

Dublin Core (DC)

DC is a metadata schema based on 15 essential properties to describe online and physical resources. Schemas are machine-processable specifications that define the structure and syntax of metadata specifications in a formal schema language⁷¹. DC elements could be combined with other vocabularies to designate the type of resource. DCMI is an extended version of DC core elements and is one of the most popular RDF vocabularies in use. Its specifications are compatible with the ideas of the Semantic Web and Linked Data (Hyvönen, 2012).

4.3 Semantic Web for Cultural Heritage

4.3.1 Challenges of cultural heritage data

Libraries, archives, and museums play a vital role in preserving cultural heritage, which was stored in different formats, such as texts, documents, media, image, and collection items. These facts accuse the heterogeneous heritage dataset. Different organizations publish cultural heritage data in various formats on the Web, which accuses the difficulty of interoperability. Moreover, as different character sets, data formats, notations, and metadata, those facts charge the problem of semantic interoperability. Semantic Web technologies are a new approach to addressing the issues. Semantic Web standards, especially those advocated by the W3C, provide a shared basis on which interoperable Web systems can be built transparently (Hyvönen, 2012, p. 5). The unifying data models that publish data on the web could address the semantic interoperability problem. Cultural heritage data have many features, such as multi-format, multi-topical, multi-lingual, multicultural, and multi-targeted. These features present some challenges that every institution that develops its metadata schema needs to consider:

Data management for cultural heritage needs to accommodate different information types relevant to the identification, description, interpretation, aesthetic appeal, technical operations, condition assessment, and historical background of art objects, monuments, and historical sites (Vavliakis et al., 2012). The management of this information is a tedious task, while efficient knowledge extraction using all these (possibly interlinking) data sources constitutes a formidable open research challenge for the next years (Vavliakis et al., 2012).

Most institutions store and publish their data in their languages and formats. To make this information available to international organizations, multilingual knowledge representation, access, and translation are an impending need (Vavliakis et al., 2012).

⁷⁰ <https://www.w3.org/TR/skos-reference/>

⁷¹ <https://dublincore.org/schemas/>

The multidisciplinary nature of analytical data requires advanced techniques for optimal data integration and knowledge reuse. Data integration should go beyond the simple merging of different concepts and URIs in an ontology (Vavliakis et al., 2012).

OWL and DL are not currently equipped with such operators for handling uncertainty, defining thresholds, and confidence levels. Thus, for the open-world assumptions, more advanced (and, as of yet, immature) techniques should be considered, such as uncertainty reasoning, representing, and reasoning under uncertainty (Vavliakis et al., 2012).

4.3.2 Semantic data models for cultural heritage

CIDOC CRM

CIDOC CRM is the Conceptual Reference Model of the International Council of Museums (ICOM) and an ISO standard since 2006. It provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation.⁷² It is event-centric, focusing on the notion of events as foundational to the creation, use, and maintenance of museum collections, documents, and objects (Doerr, 2003). It is not tied to any particular vocabulary of types, terms, and individuals. This abstraction level is useful for the semantics of the broader cultural heritage domain, as it provides a semantic framework to build a mapping between different cultural heritage resources reducing their heterogeneity. However, it does not cover the need for a finer definition of types, terms, and appellations (Vlachidis et al., 2018). The scope of CIDOC CRM is:

The CIDOC CRM has been developed in a manner that is intended to promote a shared understanding of cultural heritage information by providing a common and extensible semantic framework for evidence-based cultural heritage information integration. It is intended to be a common language for domain experts and implementers to formulate requirements for information systems and to serve as a guide for good practice of conceptual modeling. In this way, it can provide the "semantic glue" needed to mediate between different sources of cultural heritage information, such as that published by museums, libraries, and archives⁷³.

The core classes cover *E2: Temporal Entity*, *E5: Event*, *E77: Persistent Item*, *E52: Time-Span*, *E53: Place*, *E39: Actor*, *E71: Man-Made Thing*, and *E90: Symbolic Object*. Figure 2.46 shows the core class hierarchy.

⁷² <http://www.cidoc-crm.org/>

⁷³ <http://www.cidoc-crm.org/>

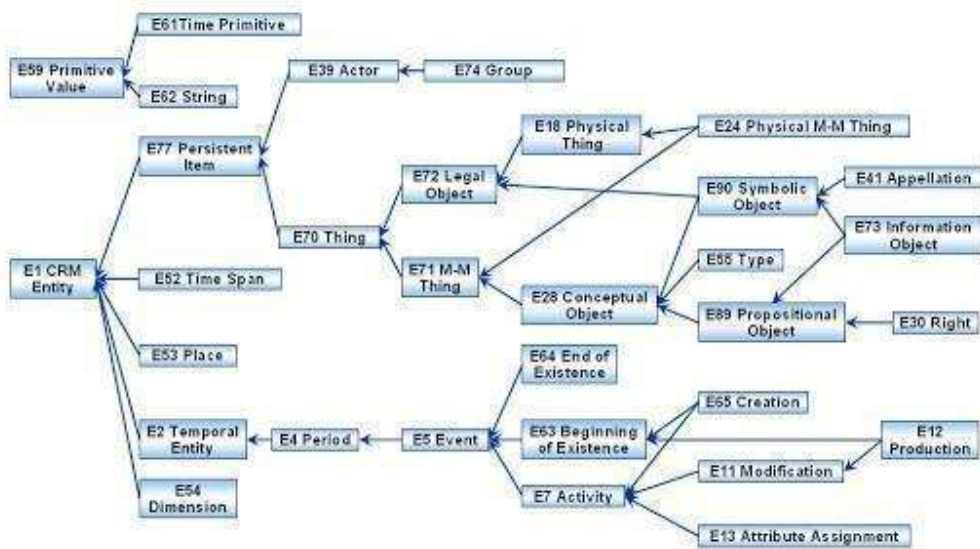


Figure 2.46. Core class hierarchy.

Europeana Data Model (EDM)

EDM aims to structure and represent the data of various contributing cultural heritage institutions delivered to Europeana, the organization tasked by the European Commission with developing a digital cultural heritage platform for Europe (Doerr et al., 2010). EDM is based on RDF and is used in the publication of Europeana contents as Linked Open Data.⁷⁴ The EDM is not a fixed schema that dictates the way of representing data. Rather, it is a conceptual framework (or ontology) to which more specific models can be attached, and interoperability between them is enhanced (Hyvönen, 2012). The core classes cover *edm:Agent*, *edm:Event*, *edm:PhysicalThing*, *edm:EuropeanaAggregation*, *edm:EuropeanaObject*, *edm:InformationResource*, *edm:NoInformationResource*, *edm:Place*, *edm:ProvidedCHO*, *edm:TimeSpan*, and *edm:WebResource*. Figure 2.47 shows the EDM classes.

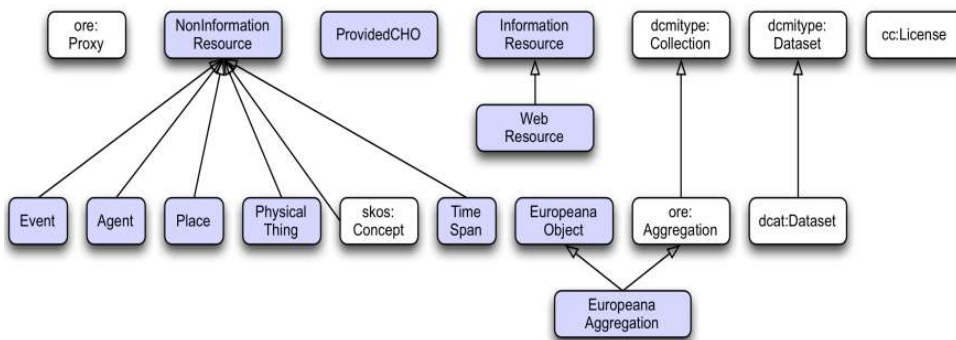


Figure 2.47. The EDM class hierarchy.

⁷⁴ <https://pro.europeana.eu/page/linked-open-data>

Lightweight Information Describing Objects (LIDO)

LIDO is an XML collection schema. The schema is intended for delivering metadata for a variety of online services, from an organization's online collections database to the portals of aggregated resources, and exposing, sharing, and connecting data on the web. It is not intended to be used as a basis for a collection management system or to support loan and acquisition activities⁷⁵. LIDO defines 14 groups of information, of which only three are mandatory, which include Object type, Title (or object name if not title), and Record ID.

4.3.3 Related work

The Art & Architecture Thesaurus (AAT)

AAT is a structured resource that can be used to improve access to information about art, architecture, and other material culture through rich metadata and links, hoping to provide (along with other Getty vocabularies) a powerful conduit for research and discovery in digital art history and related disciplines⁷⁶. The AAT is a thesaurus in compliance with ISO and NISO standards and contains terms and other information about concepts (Harpring, 2010, p. 52). The AAT is a hierarchical database and comprises over 250,000 terms on architectural history, styles, and techniques.

Kerameikos

There is a significant effort in the domain of ancient Greek pottery, which is the project Kerameikos. Kerameikos.org is a collaborative project dedicated to defining pottery intellectual concepts following the tenets of linked open data and formulating an ontology for representing and sharing ceramic data across disparate data systems⁷⁷. In Kerameikos, linked data standards have been applied in the field of Greek pottery. To develop “a discipline-specific thesaurus which serves as a bridge between existing vocabulary systems, the open-source XForms/REST/SPARQL framework for its publication, and the development of web-based tools to analyze and visualize pottery data aggregated from the Getty Museum and British Museum” (Gruber & Smith, 2014). The ontology includes five classes: *ProductionPlace*, *Shape*, *Style*, *Technique*, and *Ware*. The property is *hasShape*.

al-Andalusian pottery

The al-Andalusian pottery Ph.D project was launched by Bruno Almeida, (University Nova de Lisboa and University Savoie Mont-Blanc). This project aims to develop a representative model of al-Andalusian artifacts. It aims to establish theoretical and methodological foundations for creating an ontoterminological resource to promote terminology harmonization and further knowledge in al-Andalusian pottery studies (Almeida, 2019). It focuses on the Portuguese and Spanish terms for the al-Andalusian artifact to overcome the communication issue from a language perspective.

⁷⁵ <http://network.icom.museum/cidoc/working-groups/lido/what-is-lido/>

⁷⁶ <https://www.getty.edu/research/tools/vocabularies/aat/about.html>

⁷⁷ <http://kerameikos.org/>

Conclusion

Part II summarizes the state of the art in regard to Ontology, Terminology, Ontoterminology, and Semantic Web for cultural heritage.

The terminology chapter presents definitions, methods, theories, languages, and tools. The vital content is ISO principles of Terminology: “a term is a verbal designation of a concept” and “a concept is a unique combination of (essential) characteristics”. This chapter presented the relevant theories and methods of Terminology in our work.

The ontology chapter presented the state-of-the-art on ontology, which includes definitions, the theoretical foundation of ontologies, languages, methods, and tools. Methodologies of building domain ontology are at the core of this chapter.

The ontoterminology chapter presents the notion of ontoterminology, whose definition is “a terminology whose conceptual system is a formal ontology”. Ontoterminology makes explicit the double dimension (linguistic and conceptual) of Terminology. It unifies Terminology and Ontology into a single paradigm.

The Semantic Web for cultural heritage chapter focuses on Semantic Web and cultural heritage. Understanding the notion of cultural heritage is vital to understand this thesis work. So, at first, this chapter introduces the cultural heritage and categories of cultural heritage. The Semantic Web section includes the stack and technology standard of the Semantic Web, Linked Data, Linked Open Data, Knowledge Graph, and distinguishing between the RDF dataset, Linked Open Data, and Knowledge Graph. In the Semantic Web for the cultural heritage section, the content covered includes the challenge to cultural heritage data, as well as three kinds of the semantic standard model (CRM, EDM, and LIDO).

PART III: DOMAIN KNOWLEDGE

Chapter 1. Introduction to Chinese Ceramics

China has an extensive history of ceramics and is famous for its ceramics. The manufacturing process of ceramics is complicated, such as firing, decoration, inscription, and glaze. This chapter will focus on porcelain and introduce basic knowledge of porcelain to understand Chinese ceramics. Ceramics include porcelain and pottery whose difference is the firing temperature. The firing temperature of porcelain is higher than 1200 °C. The firing temperature of pottery is less than 1100 °C.

1.1 Glaze and Color

The glaze is a mixture of glass and crystal and a continuous vitreous layer attached to the ceramic body's surface. When iron, copper, cobalt, and other oxide metal colorants are added to glaze material, the glaze will show some colors such as blue, brown, red, and celadon under the identical firing conditions. They are called the blue glaze, brown glaze, red glaze, and celadon glaze. *Notes on Southern kiln*⁷⁸ states that glazes include a high-temperature glaze fired in the kiln and low-temperature glaze fired in the color stove. Color (彩) is one of the main decorative methods of porcelain. Colors include mainly overglaze enamel (釉上彩) and underglaze enamel (釉下彩). Each of them contains different kinds. Glazes and colors are often related.

Celadon glaze (青釉) is a famous traditional color glaze of Chinese porcelain. The color of the celadon glaze is not pure celadon, which includes moon-white (月白), sky blue (天青), light greenish-blue (粉青), light bluish-green (豆青), Dong green (冬青), and plum green (梅子青). At the time of the Ming and Qing dynasties, the Dong green of Yongle mark of the Ming dynasty and the light greenish-blue had reached the level of perfection, and many precious varieties appeared.

Black glaze (黑釉) is one of the glaze colors of ancient porcelain with black or dark brown glaze, which was paid more attention to glaze decoration and exquisite artistry in the Ming and Qing dynasties. The black glaze's primary colorants are iron oxide and small or trace amounts of manganese, cobalt, copper, and chromium. Based on pure black glazes, various low-temperature colors were applied. Black glaze became the deposit of various beautiful colors.

White glaze (白釉) is one of the glaze colors of porcelain. White glaze requires clay and glaze material with low iron content, reducing the iron content to about 1%. It is made by firing pure transparent glaze at high temperature, rather than adding white colorant in glazes. In the Song Dynasty, white glazed porcelain was mostly white with yellow teeth in a white glaze, while blue-and-white porcelain was mainly fired in the Yuan Dynasty. In the Ming Dynasty's Yongle period, white glazed porcelain reached the highest level in history, which was called "sweet white glaze" (甜白釉). In the Kangxi period of the Qing Dynasty, white glazed porcelain was like the powdered milk color, which was called "creamy white glaze" (奶白釉). Dehua kiln in Ming and Qing Dynasties has a unique style. White glazed porcelain shows pink color under the light, so-called "ivory white glaze" (象牙白釉).

⁷⁸ It is a book by Jiuyue Zhang about the Jingdezhen porcelain industry in Qing dynasty and the Chinese name is the "南窑笔记". The book was finished during the Qianlong mark of Qing dynasty.

Blue glaze (蓝釉) is one of the glaze colors of porcelain. It belongs to a high-temperature lime glaze. It is made by infiltrating a certain amount of natural cobalt raw materials as a colorant and is fired at 1280 °C - 1300 °C. The high-temperature blue glaze made in Jingdezhen (景德镇) of the Yuan Dynasty was named as "sacrificial blue" (霁蓝). In Ming and Qing Dynasties, the number of blue glaze porcelain increased. In the Xuande mark of the Ming dynasty period, the blue glaze's firing technology was mature, just like a blue gemstone, which was called "Sapphire Blue" (宝石蓝). Peacock blue is another low-temperature glaze of blue glaze.

Red glaze (红釉). The stable red glaze was the bright red created in the early Ming Dynasty. In the Jiajing mark of the Ming dynasty, the iron-red glaze (矾红) was made with iron as the colorant and is a high-temperature glaze. As a low-temperature glaze, the sacrificial red (祭红) was made in the Xuande mark of the Ming dynasty. There are many kinds of red glaze. It has evolved into different varieties according to the intensity of the color. Deep ones are ruby red (宝石红), chicken blood red (鸡血红), sacrificial red, spread red (抹红). The spread red with slight yellow was also called coral-red glaze (珊瑚红釉), which was a kind of low-temperature iron red glaze fired in the Qing dynasty and blown red glaze on the fired white glaze. The light color is generally called pink, which is kidney-bean red with the gray color (豇豆红). Rouge red (胭脂红) is also a kind of pink. Langyao red glaze (郎窑红釉) was a kind of red glaze which imitated the ruby red glaze in the Kangxi period of the Qing Dynasty. It was made of copper as the colorant and fired at a temperature of more than 1300°C.

Yellow glaze (黄釉), first appeared in the Tang Dynasty, was divided into a high-temperature glaze and low-temperature glaze. In Ming and Qing Dynasties, iron was used as a colorant for low-temperature glazes. Yellow glaze included different kinds. For example, tea dust yellow glaze, belonging to high-temperature glaze, was with a yellow-green color. The egg yellow glaze, which was created in the Kangxi period of the Qing Dynasty, was named for its color.

Green glaze (绿釉), one of the traditional glaze colors, uses copper as a colorant and lead compound as the basic auxiliary solvent. The dominant green glaze in the Ming Dynasty was peacock green glaze. In the Kangxi period of the Qing Dynasty, green glaze reached its peak, including turquoise-green glaze (松石绿), apple green glaze(苹果绿), and lake green (湖水绿).

Flambe glaze (窑变釉). It was an unexpected glaze effect in the process of firing. Because there were many kinds of coloring elements in the kiln, the porcelain may show an unexpected glaze color effect when it comes out of the kiln after oxidation or reduction.

Overglaze enamel (釉上彩) is the primary decoration method of porcelain. It is painted on the fired porcelain and then baked in the kiln. The temperature is generally from 700°C to 900°C. Because many colors can bear those temperatures, the colors are vibrant. However, because the color is on the glaze, it is easy to fade after friction or moisture. Common types of overglaze enamel are: Doucai (斗彩), five colors (五彩), pink color (粉彩), and enamel color (珐琅彩).

Underglaze enamel (釉下彩) is painted on the formed paste with color material, then applied with white transparent glaze or blue glaze, which is fired in the kiln at a high temperature that is from 1200 °C to

1250°C. The underglaze enamel includes blue-and-white (青花), underglaze brown color (釉下褐彩), underglaze brown-green color (釉下褐绿彩), underglaze red (釉里红), Five-colors (五彩).

1.2 Period

China has a history of over 5000 years. From the Xia Dynasty to Qing Dynasty, each dynasty has its glorious history. This work focuses on the Ming and Qing Dynasties. Each dynasty used the emperor's name as the reign title to indicate the date. Therefore, in this paper, the emperor's name and the Dynasty's name are used to record the date of ceramic production, such as the Hongwu mark of the Ming Dynasty (明洪武).

Ming dynasty, from 1368 to 1644, had sixteen emperors, which were Hongwu (洪武), Jianwen (建文), Yongle (永乐), Hongxi (洪熙), Xuande (宣德), Zhengtong (正统), Tianshun (天顺), Jingtai (景泰), Chenghua (成化), Hongzhi (弘治), Zhengde (正德), Shunde (顺德), Jiajing (嘉靖), Longqing (隆庆), Wanli (万历), Taichang (泰昌), Tianqi (天启), and Chongzhen (崇祯). Qing dynasty, from 1644 to 1912, had ten emperors, which were Sunzhi (顺治), Kangxi (康熙), Yongzheng (雍正), Qianlong (乾隆), Jiaqing (嘉庆), Daoguang (道光), Xianfeng (咸丰), Tongzhi (同治), Guangxu (光绪) and Xuantong (宣统). The corresponding date of each emperor is shown in Figure 3.1.

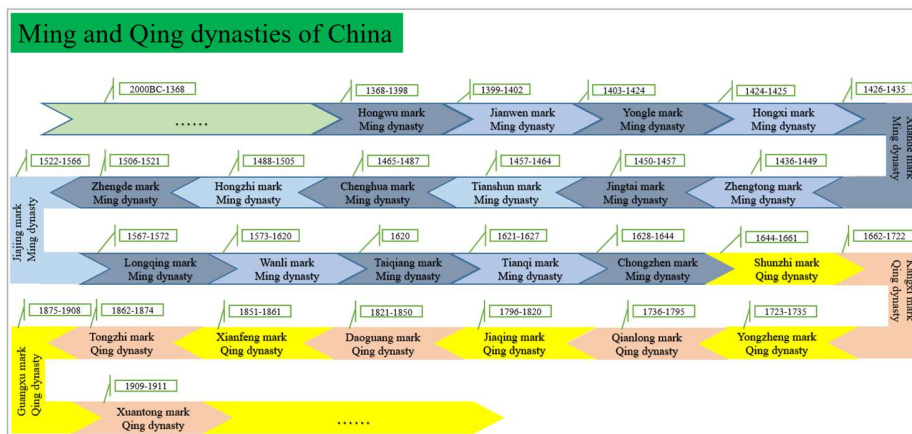


Figure 3. 1. Each emperor corresponds to the date.

1.3 Ornamentations

Ornamentation (纹饰) is a general term for decorative patterns on the surface of the ceramic. With the improvement of ceramic technology, the content of patterns changed from simple to complex. The ornamentation was from a simple bow string pattern (弦纹), mesh design (网纹) to an intricate geometric pattern (几何纹), plant pattern (植物纹), animal pattern (动物纹), and figure pattern (人物纹). With the change of era, animals and plants are given auspicious meanings in patterns. As there are many patterns, it is impossible to list all kinds.

Plant pattern (植物图). Various decorative crafts are used to draw plant patterns on the surface of ceramics. The most popular plant patterns were the lotus flower pattern (莲花图), lotus petal pattern (莲瓣图), peony

pattern (牡丹图), and plantain leaf pattern (蕉叶图). The lotus flower pattern was one of the earliest designs used to decorate porcelain. Lotus flower pattern was expressed in various forms, such as winding branches (缠枝), plucked branches (折枝), and overextended branches (过枝). Lotus petal pattern was decorated with lotus petals. According to the level of decorative lotus petals, it could be divided into single-layer lotus petals, double lotus petals, and multiple lotus petals. Peony pattern, one of the typical decorations of porcelain, refers to the pattern with a peony theme. Since the Tang Dynasty to the Qing Dynasty, peony had been popular with decoration. The plantain leaf pattern was also a typical decorative porcelain pattern and was painted on the neck or near the bottom of porcelains.

Animal patterns (动物图) are a kind of animal patterns with a particular auspicious significance. More popular animal patterns included crane (鹤), dragon (龙), bird (鸟), fish (鱼), Phoenix (凤凰), mandarin duck (鸳鸯). Crane pattern (仙鹤图) implies longevity. In the Ming and Qing Dynasties, most of the porcelains were painted with Red-crowned crane and “寿” character, forming a longevity pattern. The dragon is a mythical animal in China and a symbol of power and status. Therefore, the dragon pattern (龙图) was often used as decoration on ancient palace porcelain. Dragon pattern was often combined with phoenix pattern to make dragon and phoenix pattern (龙凤图), merged with a flower pattern to form dragon and flower pattern (穿花龙图), and combined with pearl pattern to create the Pearl of dragon opera (龙戏宝珠图). Bird pattern (鸟图) includes all kinds of bird patterns. The bird pattern was usually not used as patterns alone and often combined with other patterns. Fish pattern (鱼图) was often made on ceramics' surface by a variety of decorative crafts, such as carving and painting. Fish has an auspicious meaning in China, so it was very popular with porcelain decoration. Phoenix is a kind of ancient mythical bird. Many porcelains were decorated with phoenix patterns (凤凰图) in Ming and Qing Dynasties. Mandarin duck is a symbol of love, so it often appears in ceramic pairs as decorative patterns. In Ming and Qing Dynasties, the Mandarin Duck pattern (鸳鸯图) was made in blue and white or Doucai.

Figure patterns (人物图) are decorative patterns that reflect the personage's social activities and historical stories. The Figure pattern mainly included a pattern of children at play (婴戏图), a pattern of beauties (美女图), a pattern of farming work and weaving (耕织图), a pattern of eight immortals (八仙图), and pattern of the historical story (历史故事图). The pattern of children at play was based on children's play scenes, which were popular in the Ming and Qing Dynasties. Performance techniques included blue-and-white, multi-colored, and pink color. The pattern of beauty was based on the graceful posture of beautiful women at that time. The pattern of farming work and weaving displayed the working scene of farming and weaving. The eight immortals pattern was based on the eight immortals of Taoism, which were popular during the Ming Dynasty. The historical story pattern, with the theme of the historical story, was popular in the Yuan, Ming, and Qing Dynasties.

1.4 Kilns

The kiln is where ceramics were produced. Kilns include official kilns and civilian kilns. The government built official kilns to produce ceramic wares for the palace. The civilian kiln, compared with the official kiln, is a folk kiln. In the Ming and Qing Dynasties, when the court established official kilns in Jingdezhen, many civilian kilns were also used. There are several examples of kilns, whose locations are shown in Figure 3.2.

Dehua kiln (德化窑), located in Dehua County, Fujian Province, was an important place for porcelain export in Ming and Qing Dynasties. It produced blue and white or white glazed porcelain.

Jingdezhen kiln (景德镇窑), a vital porcelain producing area in China, is located in Jingdezhen. During the Ming and Qing Dynasties, Jingdezhen kiln produced blue and white porcelain, multicolored porcelain, and overglaze porcelain.

Shiwan kiln (石湾窑), located in Shiwan, Foshan city, Guangdong Province, is an important ancient ceramic production area in Guangdong Province. In the Ming Dynasty, many black glazes were fired in the Shiwan kiln. In the Qing Dynasty, ink color (墨彩) and emerald glaze (翠毛釉) were particularly prominent.

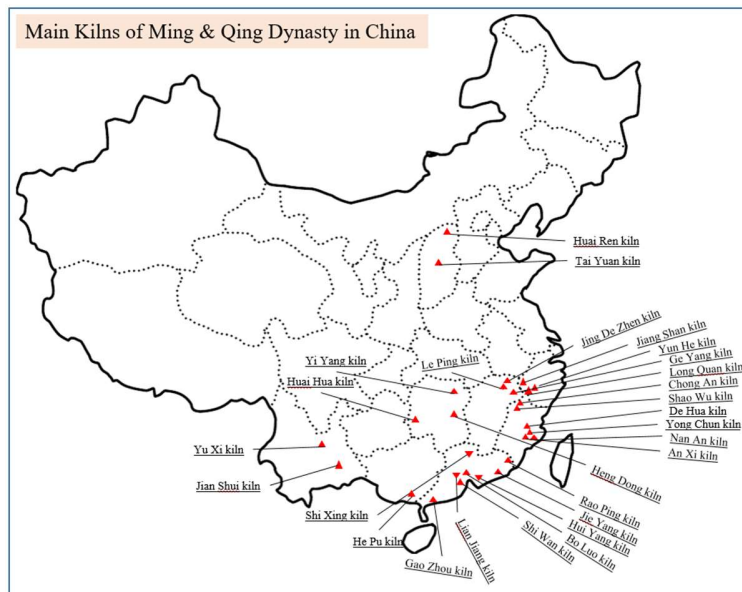


Figure 3. 2. The kiln corresponds to the location.

Cizhou kiln (磁州窑) was the largest civilian kiln in the north of China. It made black porcelain (黑瓷), white porcelain (白瓷), white ground black (白地黑), and brown color porcelain (褐彩瓷).

1.5 Decoration crafts

Decoration craft uses various techniques to carry out decoration treatment, such as carving, incised, and drawing on ceramics' surface or paste. Decoration crafts include paste decoration (胎装饰), glaze decoration (釉装饰), and colored drawing decoration (彩绘装饰). Paste decoration refers to ceramic products' decoration processing with such techniques as carving, incised, pasting. Paste decoration mainly divided into decoration carved in the paste (划花), incised decoration (刻花), incised and carved design (刻划花), stamped decoration (印花), cut decoration (剔花), and applied floral design (贴花). Glaze decoration is mainly through applying different glazes, which produces different effects after firing. Colored drawing decoration refers to the use a variety of color materials to paint on ceramic paste before firing.

Decoration can be carved in the paste and is one of the decorative techniques of ceramics. On the surface of the half-dried paste of the ceramic, a line like a flower pattern was scratched with bamboo, wood, iron, and other tools, and then it was glazed or baked in the kiln.

The incised decoration is one of the decorative techniques of ceramic ware. When ware paste had not dried thoroughly, the pattern was carved on the ware paste's surface with an iron knife and other tools, and then glazed or baked directly.

The stamped decoration was produced by using the tool made of a ceramic material with flower patterns to stamp floral patterns on the body of the unfinished ware, or by making a paste with patterned molds and leave patterns directly on the paste body, and then putting it into the kiln or putting it glazed into the kiln for firing.

The cut decoration is the primary decorative technique of ceramic ware. First, glaze or make-up soil was applied on the surface of the ware's paste, and the pattern was carved, then the glaze layer or make-up soil outside the pattern part or pattern was removed to expose the paste.

Applied floral design is one of the decorative techniques of porcelain. Applied floral design was patterns of various Figures, animals, and flowers that were molded or kneaded, pasted on the surface of the shaped object paste with mud chips or mud, and then glazed and fired in the kiln.

Chapter 2. Chinese Ceramics of the Ming and Qing Dynasties

Kathryn L. Ness proposed “using a vessel-based classification system will allow archaeologists to explore deeper questions regarding behavior and emic (user-ascribed) views of the objects recovered in excavations as well as provide a way of comparing Spanish and Spanish-American ceramic assemblages” (Ness, 2015). Toby Schreiber focused on “analysis of the construction methods used by attic potters in the forming of their vases” (T. Schreiber, 1999). Sophia-Karin Psarras analyzed the “Han dynasty (206 BC-AD 220) Chinese archaeology based on a comparison of the forms of vessels found in positively dated tombs.” (Psarras, 2015). C. Orton provided “an up-to-date account of the many different kinds of information that can be obtained through the archaeological study of pottery.” (Orton & Hughes, 2012). This divergence reflects different views of archaeology on the two continents, as European archaeology is often closely allied to history, while American archaeology is typically seen as a subfield of anthropology (Ness, 2015).

This chapter will present the reason for choosing the Ming and Qing dynasties. It will also introduce the evolution of their shapes and the regularity of naming Chinese ceramic vases.

2.1 Reasons for Choosing Ming and Qing dynasties

Ming Dynasty (1368-1644) ceramics were famous for the boldness of their form and decoration and the varieties of design.⁷⁹ In 1402, the Ming Emperor Jianwen ordered an imperial porcelain factory in Jingdezhen to produce porcelain for court use in state and religious ceremonies and tableware and gifts. There were many famous kilns and many different ceramic vessels from the Tang dynasty to the Song dynasty. From the beginning of the Ming dynasty, the Jingdezhen kiln gradually became the most critical production place. Ceramic vessels of the Jingdezhen kiln represented the highest quality at the time. Between 1350 and 1750, Jingdezhen was a production center for nearly all of the world's porcelain. Their export and trade had already begun in the Tang dynasty, but only on a small scale. The export trade of ceramic vessels was significantly developed in the Ming dynasty, thanks to Zheng He, a famous navigator, and diplomat. He, between 1405 and 1433, began to sail to the Western Pacific. In the 80 years from the 30th year of the Wanli mark in the Ming Dynasty (1602) to the 21st year of the Kangxi mark in the Qing Dynasty (1682), 12 million Chinese pieces porcelain were trafficked to Europe by the Dutch East India Company⁸⁰. In recent years, many ceramics of the Ming and Qing dynasties were found in Southeast Asia, Europe, America, and Mexico (冯先铭, 2002).

Qing dynasty (1644-1911) porcelain was famous for its polychrome decorations, delicately painted landscapes, and bird and flower as well as multicolored enamel designs. The peak of Chinese ceramics production took place in the reigns of Kangxi (1661-1722), Yongzheng (1722-1735), and Qianlong (1735-1796) during which improvement was seen in almost all ceramic types, including the blue and white wares,

⁷⁹<http://factsanddetails.com/china/cat7/sub40/item258.html#chapter-11>

⁸⁰https://news.cgtn.com/news/3d3d674d7863444f7a457a6333566d54/share_p.html

polychrome wares, monochrome wares.⁸¹ During the Qing dynasty, potters began using bright colors to adorn plates and vases with meticulously painted scenes. Potters continued developing a five-colored ware by applying a variety of pigments to floral, landscape, and figurative scenes – a style which was (and is) highly sought-after in the West.⁸² The Qing dynasty is a period especially noted for the production of color glazes. Qing potters succeeded in reproducing most of the popular glaze colors found in ceramic wares of the Song, Yuan, and Ming dynasties. Besides, they created various new glazes, thus bringing a vibrant energy to Chinese porcelain art⁸³.

2.2 Presentation of vessels

Vessel is defined as “A hollow container, especially one used to hold liquid, such as a bowl or cask”⁸⁴. In the domain of Chinese ceramics, there are many different vessels, such as vase (瓶), cup (杯), bowl (碗), box (盒), jug (壶), basin (盆), Bo (钵), censer (炉), plate (盘), Gu (觚), Jar (罐), He (盃), and Dou (豆).

Vase (瓶), a decorative container, typically made of glass or china, and used as an ornament or displaying cut flowers (Kipfer, 2007, p. 332). Chinese ceramics include many different types of vases according to the shape of vases.

Cup (杯), a small, round container, often with a handle, is used to drink tea and coffee (Walter, 2008, p. 341).

Box (盒), a square or rectangular container with stiff sides and sometimes a lid (Walter, 2008, p. 162).

Bowl (碗), a round container that is open at the top and is deep enough to hold fruit, sugar (Walter, 2008, p. 161).

Jar (罐), a glass or clay container with a wide opening at the top and sometimes a fitted lid, is usually used for storing food (Walter, 2008, p. 770).

Jug (壶), a container for holding liquids that has a handle and a shaped opening at the top for pouring (Walter, 2008, p. 780).

Basin (盆), an open, round container shaped like a bowl with sloping sides, is used to hold food or liquid (Walter, 2008, p. 109).

Bo (钵) is a ceramic container for washing or holding things. It is a smaller ceramic ware shaped like a basin with a wide mouth and a rounded or flat bottom, used to hold rice, vegetables, tea⁸⁵. Generally speaking, it refers to the food utensil used by monks

⁸¹ <https://www.comuseum.com/ceramics/qing/>

⁸² <https://www.comuseum.com/ceramics/qing/>

⁸³ <https://www.comuseum.com/ceramics/qing/>

⁸⁴ <https://www.oxfordify.com/meaning/vessel>

⁸⁵ <https://casadimosca.ru/en/kak-nazyvaetsya-sosud-v-forme-stakana-s-ruchkoi-kak-nazyvaetsya.html>

Censer (炉) is a container in which incense is burned, typically during a religious ceremony (Kipfer, 2007, p. 152).

Gu (觚) is a container for drinking wine in ancient China. It is a slender beaker with a trumpet-shaped mouth and spreading foot (Hansford, 1961, p. 6).

He (盃), a rounded vessel with a closed spout, handle, cover, and three or four legs, solid, or hollow (Hansford, 1961, p. 6).

Dou (豆), a hemispherical bowl raised on a high stem with spreading foot: usually with a cover which may be inverted for use as a separate vessel (Hansford, 1961, p. 5).

Plate (盘) is a flat, usually round dish with a slightly raised edge that could use to eat from or serve food from it (Kipfer, 2007, p. 244).

2.3 Presentation of vases

Many people would like to focus on analyzing material composition or technique of glaze, decoration, and making for ancient Chinese ceramics research. There are little researchers to study the shape of ceramics and distinguish them. Therefore, it has value to analyze the shape of ceramics to understand ceramics and build classification systems according to shape in the Semantic Web.

Plum vase (梅瓶): The plum vase is also called *Mei* (“plum” in English) *Ping* (“vase” in English) because of its shape of the mouth, which made it suitable for holding a bough of blossoming plum⁸⁶. “The form made its appearance in about the 10th century or a little earlier and had remained popular ever since” (Medley, 1975, p. 77). In Ming and Qing dynasties, the term “plum vase” denoted the different types of vases (Figure 3.3, 3.4). For example, Figure 3.5.a shows the plum vase is with a top, foot, small mouth, short neck, and swelling body tapering downwards. Figure 3.5.b displays the plum vase is with a small mouth in the shape of a lip, short neck, swelling body tapering downwards, foot, and without a lid.

Arrow vase (贯耳瓶): An arrow vase is with a long cylindrical neck, at the top of which are two cylindrical lugs. The vase was used for the 'arrow game' in which arrows were thrown by competitors, who attempted to get them into a vase or through lugs (Medley 1975, p. 59). The term “arrow vase” denoted the different types of vases. For example, Figure 3.5.c shows the arrow vase is with a circle mouth, slanting shoulder, and ring foot, while Figure 3.5.d displays the arrow vase is with a square mouth and square foot.

⁸⁶ <https://gotheborg.com/glossary/meiping.shtml>

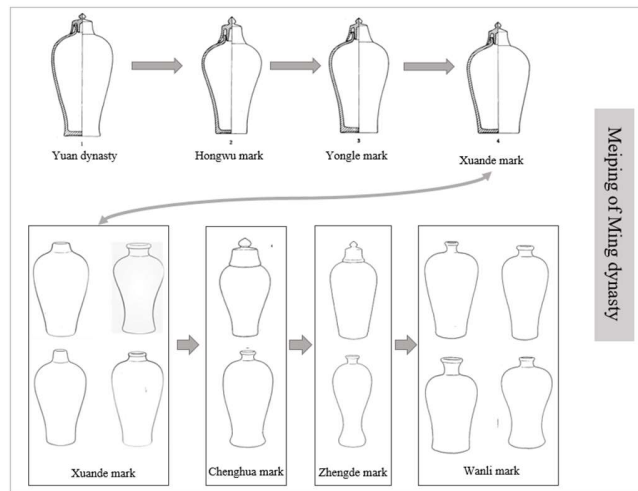


Figure 3. 3. Plum vase evolution process of Ming dynasty.

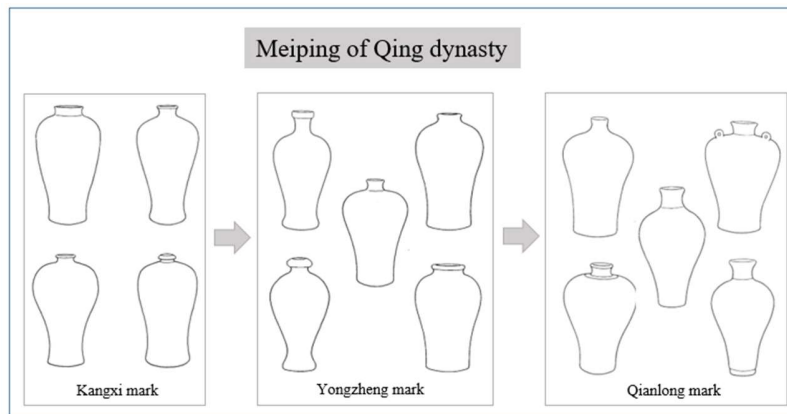


Figure 3. 4. The plum vase evolution process of the Qing dynasty.

Garlic-head Vase (蒜头瓶): Because its mouth likes garlic, it is named “garlic-head vase”. Usually, its shape is garlic mouth, long neck, globular body, and ring foot (冯先铭, 1998, p. 139). However, during the Ming and Qing dynasties, the term “garlic-head vase” denoted the different types of vases. Figure 3.5.e shows the garlic-head vase is with a long and slender neck and high ring foot, while Figure 3.5.f introduces the garlic-head vase with a short neck, handles, and short ring foot.

Pear-shaped Vase (玉壶春瓶): A pear-shaped vase is with a contracted neck and flaring up. As a ceramic form, it probably appeared first in the latter part of the T'ang Dynasty. The Chinese call this form yu-hu-ch'un-p'ing, which could be found in some modern writings (Medley 1975:60). There are two reasons for naming it as “玉壶春瓶”. One is according to Su Dongpo’s verse “玉壶先春、冰心可鉴” (苏燕, 2011). Another used to hold famous alcohol that was called yu-hu-Chun in Changan and Luoyang during the T’ang dynasty (钱秋虹 & 谢建明, 2014). Figure 3.5.g shows an example of the pear-shaped vase.

Cong-shaped vase (琮式瓶): Cong, essential tubes with a square cross-section and a circular hole⁸⁷. “a hollow tube of cylindrical section enclosed by a rectangular body (the symbol of the deity earth)” (王殿明 & 杨绮华, 2005, p. 172). In different dynasties, the shape of the Cong-shaped vase was the similarity (Figure 3.5.h).



Figure 3. 5. Different types of vases.

Rouleau vase (棒槌瓶): The term applies to this type of vase produced from the late 17th century onward (Medley, 1975, p. 81). Because its shape looked like a wooden stick used for washing clothes, it was named Rouleau vase. For example, Figure 3.6.a displays the Rouleau vase is with a plate-shaped mouth, straight neck, cylindrical belly, and ring foot.

Square Rouleau vase (方棒槌瓶): A vase is with an outward mouth, short neck, flat shoulder, square belly, and square foot (冯先铭, 1998, p. 143; 耿宝昌, 1993, p. 191). Figure 3.6.b is an example of the square Rouleau vase.

Double-gourd vase (葫芦瓶): It was named “double-gourd vase” because its shape looks like a gourd. The term “double-gourd vase” denoted the different types of vases in different dynasties. For example, Figure 3.6.c introduces the double-gourd vase that was made in the Chenghua mark of the Ming dynasty, is with a small mouth and ring foot, while Figure 3.6.d shows the double-gourd vase, made in the Qianlong mark of Qing dynasty, is with a small mouth, handles, and square foot. Figure 3.6.e displays the double-gourd vase was made in the Qianlong mark of the Qing dynasty and is with a lid and small mouth.

Moon shaped vase (宝月瓶): A full-moon shaped vase was also called as moon flask (Medley1975:79). The moon flask was with underglaze blue or polychrome enamel decoration and dated from the 15th century onward. The shape of the moon flask is displayed in Figure 3.6.f.

⁸⁷ <https://gotheborg.com/glossary/cong.shtml>



Figure 3. 6. Several different types of vases.

Long neck vase (长颈瓶): The long neck vase's principal feature was with a long neck. In different dynasties, the long neck vase had different styles. For example, Figure 3.6.g shows the long neck vase was made in

Cylindrical vase (筒瓶): Because of its shape likes an elephant leg, it was also named “elephant leg vase”. It was popular with the late Ming dynasty and the whole of the Qing dynasty. Figure 3.7 shows the evaluation process of the cylindrical vase. For example, Figure 3.8.f shows a cylindrical vase made in the Shunzhi mark of the Qing dynasty.

Water-chestnut vase (荸荠扁瓶): Because its belly likes a water-chestnut, it was called as “荸荠扁瓶”. Figure 3.8.a shows an example of a water-chestnut vase, which was made in the Yongzheng mark of the Qing dynasty.

Vault-of-Heaven vase (天球瓶): Because of its shape like a celestial sphere, it was named as a vault-of-Heaven vase. The term “vault-of-heaven vase” denoted different types of vases in different periods. For example, the vase is with a ring foot in Figure 3.8.b, while the vase is with a concave foot in Figure 3.8.c.

Twin vase (双连瓶): The vase was named as a twin vase because it was connected with two vases. Twin vases had multi-mouth or multi-belly. For example, Figure 3.8.d shows an example of a twin vase made in the Qianlong mark of the Qing dynasty.

Lantern-shaped vase (灯笼瓶): It was named “lantern-shaped vase” because the vase liked a lantern (冯先铭, 1998, p. 144). In the Ming and Qing dynasties, the lantern-shaped vase was often with an outward mouth, short neck, slanting shoulder, cylindrical belly, and ring foot (Figure 3.8.e).

Gall-bladder vase (胆式瓶): Because its shape liked a gall-bladder of an animal, it was named as a gall-bladder vase (冯先铭, 1998, p. 142). The term “gall-bladder vase” denoted the different types of vases in different dynasties. For example, Figure 3.8.g and Figure 3.8.h are types and are differences in the mouth and belly of vases.

Awl-handle vase (锥把瓶): Its shape was the same as the awl-handle, so it was named an awl-handle vase. It is critical to distinguish the awl-handle vase, gall-bladder vase, and oil-hammer vase. The awl-handle vases' neck was slender than gall-bladder and wider than oil-hammer vase (冯先铭, 1998, p. 143). There is an example of an awl-handle vase in Figure 3.9.a.

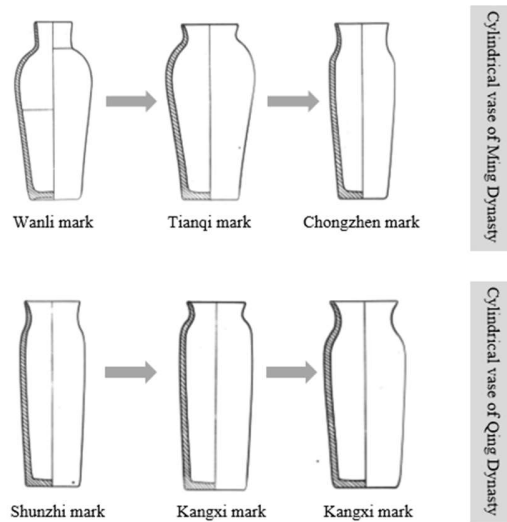


Figure 3. 7. The process of cylindrical vase evaluation.



Figure 3. 8. Different types of vases.

Oil-hammer vase (油锤瓶): Like a hammer used for the ancient oil industry, it was named an oil-hammer vase that shape is similar to the awl-handle gall-bladder vase. The neck of the oil-hammer vase is the slenderest, and the belly is globular (冯先铭, 1998, p. 143) (Figure 3.9.b).

Olive-shaped vase (橄榄瓶): Because its shape liked olive, it was called as an olive-shaped vase (冯先铭, 1998, p. 142). The olive-shaped vase was famous in the Qing dynasty and denoted the different types of vases. Figure 3.9.c displays the olive-shaped vase with a straight mouth and short neck, while Figure 3.9.d shows the olive-shaped vase is with an outward mouth, slender and long neck.



Figure 3. 9. Different types of vases.

Losing ring vase (活环瓶): Because the vase was with losing ring in handles, it was named “活环瓶”. Figure 3.9.e is an example of the losing ring vase.

Willow-leaf-shaped vase (柳叶瓶): The vase liked a willow leaf, so it was named as a willow-leaf-shaped vase. Another name is “beauty-shoulder vase” because it seems like a beautiful girl’s shoulder (冯先铭, 1998, p. 144). Its shape was outward mouth, short neck, slanting shoulder, swelling body tapering down, and with the foot (耿宝昌, 1993, p. 191). For example, Figure 3.9.f shows an example of a willow-leaf-shaped vase.

Reward vase (赏瓶): It was made in the Yongzheng Period of the Qing dynasty and was used to reward an official who has rendered outstanding service. The reward vase adopted a fixed pattern of ornamentation that “青花蕉叶纹 (banana leaf pattern of Blue and white)” was located on the neck of the vase and “缠枝莲纹 (interlock branch lotus pattern⁸⁸)” was located on the belly of the vase (Figure 3.9.g). The Chinese character “青” (“blue-green” in English) has the same pronunciation as a character “清” that means distinct. The Chinese character “莲” (“lotus” in English) has the same pronunciation as a character “廉” which means incorruptible. So, the Chinese term “青莲” are combined to represent “清廉” that means uncorrupted for official. The reward vase reflected the social aspiration that politics would be no corruption in the middle and late Qing dynasty (冯先铭, 1998, p. 145).

⁸⁸ It expressed the lotus a lot, and the branches of lotus twined each other.

Double-tube vase (双管瓶): The double-tube vase was with double neck and double mouth. Its shape was particular. For example, Figure 3.9.h shows the double-tube vase was made in the Kangxi mark of the Qing dynasty.

2.4 Chinese Ceramic Terminology

2.4.1 Regularity of naming and translation of Chinese ceramics

Chinese ceramic vessel terms are made up of characters that convey information about the objects of which they are the names. The head of the term (rightmost character) corresponds to the type of the object, such as a vase (瓶, *píng*), plate (盘, *pán*), bowl (碗, *wǎn*), cup (杯, *bēi*), basin (盆, *pén*), jug (壶, *hú*), jar (罐, *guàn*). The additional characters are modifiers about glaze and color, ornamentation, shape, kiln, period (dynasties+mark). (杨红英 & 马海滢, 2012). The Nanjing museum adopts the following order of modifiers for naming Tibetan ceramics (霍华, 1989): dynasty + kiln + glaze + color + decoration + shape + texture + type, e.g., “清雍正粉青釉凸花如意耳蒜头瓷瓶”. We can notice that without any explanation being given, but perhaps for paraphrase reasons. The English translation of the Nanjing museum's Chinese terms does not follow this order, but the following order: glaze + color + shape + texture + type + decoration + period + kiln. For example, the term “清雍正粉青釉凸花如意耳蒜头瓷瓶” is translated as follows: “powder blue glaze garlic porcelain vase designed with flowers and Ru-Yi handles, the Yongzheng mark of the Qing dynasty”.

The information conveyed by the modifiers expresses knowledge of different types, either essential, such as shape, material, and type, or descriptive, like glaze and color. Let us see in more detail some modifiers that compose Chinese terms of ceramic vessels with the following example: “清德化窑白釉堆雕花卉瓷碗” whose English translation is “white glaze porcelain bowl with sculpted flowers, Qing Dynasty Dehua kiln.”

Dynasty: the terms contain the character denoting the dynasty and, when it is known, the character corresponding to the emperor. For example, in “清德化窑白釉堆雕花卉瓷碗”, the character “清” represents the Qing dynasty, without any indication about the emperor which, in this case, is not known.

Kiln: Since the type of kiln is vital in the manufacturing process, it is part of the vessel's designation. Although the Jingdezhen kiln became the center of the national ceramics industry during the Ming and Qing dynasties, there were other kilns, such as the Shiwan kiln, DeHua kiln. In “清德化窑白釉堆雕花卉瓷碗”, The “德化窑 (*dé, huà, yáo*)” designates the “DeHua kiln”.

Glaze and color: The most famous in Ming and Qing dynasties are blue-and-white. Other types of glaze and color include underglaze red, greenish-white, and white glaze. In “清德化窑白釉堆雕花卉瓷碗,” the “白釉 (*bái, yòu*)” refers to “white glaze”.

Decoration: it includes the technique of pattern made in a ceramic vessel and decoration pattern. The technique comprises stamped decoration, incised decoration, incised, and carved design. Patterns include flowers, trees, landscapes, figures, and animals. In “清德化窑白釉堆雕花卉瓷碗,” the “堆雕花卉 (*duī, diāo, huā, huì*)” refers to the decoration and is translated as “sculpted flowers.”

Shape: some characters express the shape of vessels or parts of it, such as pear-shape, tubular-shape. For example, in “清雍正粉青釉凸花如意耳蒜头瓷瓶,” the “蒜头 (*suàn, tóu*)” is translated as “garlic”, a metaphor for the shape of the mouth of vases.

Texture: the texture includes pottery and porcelain. In our case, the texture refers to the porcelain. In “清德化窑白釉堆雕花卉瓷碗,” the character “瓷 (*cí*)” means “porcelain”.

Type: the type of vessel, i.e., a plate, a bowl, a basin, a jar, a vase, jug, box, cup. For example, in “清德化窑白釉堆雕花卉瓷碗,” the “碗 (*wǎn*)” is translated as “bowl”, which is typical.

2.4.2 Analysis of Chinese ceramic terminology

Chinese ceramic terms are composed of Chinese characters. A Chinese character often represents a term, such as a vase (瓶, *píng*), cup (杯, *bēi*), bowl (碗, *wǎn*). There are also compound terms, such as double gourd vase (葫芦瓶, *hú lu píng*), plum vase (梅瓶, *méi píng*). Whether it is monosyllabic terms or compound terms, the most basic constituent unit is Chinese characters. The Chinese characters that make up the ceramics terms reflect the characteristics of the objects denoted by terms. Therefore, in ceramic terminology, understanding the meaning of Chinese characters helps understand ceramic terminology. The following is an example analysis of ceramics terms from a different perspective.

The vessel term is the focus of this thesis and is also the basis of subsequent modeling, such as double gourd vase (葫芦瓶, *hú lu píng*), plum vase (梅瓶, *méi píng*), pear-shaped vase (玉壶春瓶, *yù hú chūn píng*), garlic-head vase (蒜头瓶, *suàn tóu píng*). These vessel terms reflect the shape characteristics of the objects denoted by the terms. For example, the term “double gourd vase” is composed of two terms: double gourd (葫芦, *hú lu*) and vase (瓶, *píng*). Chinese character double gourd (葫芦, *hú lu*) has the same radical: 艹, which means plant. The term “double gourd” refers to the herbaceous plant whose fruit is thin in the middle, like two balls connected. In ceramic terms, double gourd vase (葫芦瓶, *hú lu píng*) refers to the shape characteristics of vases like a gourd, so it is called double gourd vase.

For example, in the term “明 万历 五彩 穿花龙纹 蒜头 瓷 瓶”, the term “瓶” means a vase. The term “明” refers to the Ming dynasty, and the term “万历” refers to the name of the Wanli emperor. The term “五彩” reveals the characteristics of the glaze. The term “蒜头” is used to describe the shape of a vase. The Chinese character “瓷” means “porcelain” and is composed of “次” and “瓦”. The “瓦” means pottery, and “次” represents order or the next step. Therefore, the next stage of pottery will be porcelain after high temperature. The combination of “次” and “瓦” forms the Chinese character “瓷”, which means porcelain.

So, understanding the meaning of Chinese ceramic terms needs to know the regularity of naming ceramics and needs to understand the combination of morphological, phonological, and meaning of the Chinese characters, which are composed of the Chinese ceramic term.

Conclusion

Our work focuses on Chinese ceramic vessels. Chinese ceramic knowledge is significant in building the TAO CI ontology. This included glaze and color, kiln, period, ornamentation, and decoration craft. By presenting the knowledge of ceramics, the reader could comprehend the TAO CI ontology developing.

Chapter 2 presented the feature of the Ming and Qing dynasties' ceramic vases as the research object and the reason. The research objects were from different Chinese museums. The reasons include the technique level, history, and influence. Also chapter 2 discusses the rule of naming ceramics: for example, following the pattern “dynasty + kiln + glaze + color + decoration + shape + texture + type”, while the translation of Chinese ceramic names follows the pattern “glaze + color + shape + texture + type + decoration + period + kiln”. Through analyzing the terms of Chinese ceramic vases, one can get important information for developing the TAO CI ontology.

**PART IV: ONTOTERMINOLOGY OF THE CHINESE
CERAMIC VESSEL**

Chapter 1. Term-and-Characteristic guided Methodology

1.1 Introduction

What follows is a list of well-known methodologies of ontology building (Corcho et al., 2003; Gruber, 1995; Uschold & King, 1995). These methods are based on objective criteria, e.g., clarity, coherence, extensibility (Gruber, 1995), and are inspired by different fields, such as knowledge-base development (Lenat & Guha, 1989), software engineering methods (Fernández-López, 1999), text-based construction (Zouaq & Nkambou, 2009), modular design approach (Desprès, 2014; Özacar et al., 2011), unsupervised domain ontology learning method (Venu et al., 2016), ontological engineering (Suárez-Figueroa et al., 2012), and based on the formal concept analysis (Nong et al., 2019). Let us quote some methods that focus on the stages which compose them. CommonKADS (Schreiber et al., 1994), which is not per se a methodology for ontology development, but a leading method to support structured knowledge engineering, includes three phases: context, concept, and artifact. CommonKADS focuses on the initial stages for developing knowledge management applications. METHONTOLOGY (Fernández-López et al., 1997) aimed to reduce the gap between ontological art and ontological engineering and focused on comprehensively addressing the maintenance stage of the life cycle of the ontology and had seven stages: specification, knowledge acquisition, conceptualization, integration, implementation, evaluation, and documentation. On-To-Knowledge Methodology (Sure et al., 2004) was a methodology that supported the systematic introduction of knowledge management solutions into enterprises, which covered the following several phases: feasibility study, kickoff, refinement, evaluation, and application & evolution. NeOn methodology (Suárez-Figueroa et al., 2015) did not prescribe a rigid workflow, but instead, it suggested a variety of pathways for developing ontologies. Nine scenarios proposed in NeOn methodology covered commonly occurring situations when available ontologies needed to be re-engineered, aligned, modularized, localized to support different languages and cultures, and integrated with ontology design patterns and non-ontological resources. However, domain experts had challenges building domain ontologies based on the above methodologies because experts with domain knowledge are rarely versed in model or ontology development and did not know the formal languages or logic that express ontological concepts.

Term-and-characteristic guided methodology is derived from works carried out in Digital Humanities (Roche & Papadopoulou, 2019), taking into account the two following ISO principles of Terminology: “a term is a verbal designation of a concept” and “a concept is a unique combination of (essential) characteristics” (ISO 1087-1, ISO 704). The term-and-characteristic guided approach follows the primary idea that domain experts know their domain terms, and a concept is a set of essential characteristics, which is stable enough to be named by a term in a natural language. Then, domain experts find the essential characteristics of concepts denoted by terms. Then, the terms guide domain experts to define the formal concepts denoted by terms. Although any combination of (essential) characteristics potentially defines a possible concept, not all of those combinations are meaningful for the domain experts. Thus, terms can be considered as many guides for building ontology if we think that a concept is a set of essential characteristics that is stable enough to be named by a term in a natural language. The problem is then moved to identify essential characteristics, which becomes the primary phase of our methodology. This phase is based on identifying differences between objects (vases with neck *versus* vases without neck) and morphological

analysis of Chinese terms whose characters carry meaning concerning the denoted objects. For example, in the term "清德化窑白釉堆雕花卉瓷碗", the first character (清) represents the Qing dynasty and the last one the type of vase(碗). The functions of terms in our work are to provide the guidance of constructing concepts and provide essential characteristics.

Let us recall some definitions of glossaries in the term-and-characteristic guided methodology. The definition of concept follows the ISO principles of Terminology (ISO 1087-1 and 704), which defines a **concept** as a “unit of knowledge created by a unique combination of *characteristics*.” The characteristics refer to the essential characteristics, which is the characteristic of a concept that is indispensable to understand that concept. The concept would be regarded as an identity. Namely, it could be regarded as an identity criterion for judging which class an individual belongs to in ontology (Guarino & Welty, 2004). The **essential characteristic** is an abstract of property. The essential characteristic could correspond to rigid predicates in DL (Guarino & Guizzardi, 2006) and rigid properties in the OntoClean method (Guarino & Welty, 2004). **Descriptive characteristic** is another kind of characteristic, but it is unlike the essential characteristic. According to ISO 704, The descriptive characteristic does not constitute a concept, and it just plays a supplementary role to describe the object, such as the color, weight, length characteristic. Descriptive characteristics are not rigid properties. **Terms** are defined as “designation that represents a general concept by linguistic means” in ISO 1087-1.

Let us note that our methodology does not include a “term extraction” phase since the terms that denote vases are known by experts.

1.2 Workflow of methodology

Ontology building follows a lifecycle made up of several stages: specification, conceptualization, implementation, and evaluation stages (see, i.e. (Fernández-López et al., 1997)). Some of those stages have to be specialized, and others can be introduced to consider the domain's specificities and objectives. Term-and-characteristic guided methodology includes eight steps (Figure 4.1). Each stage has different tasks.

Step 1: Identify the scope of the domain and the objectives. This step is the beginning of building ontology. The aim is to define the scope of the project and its objectives. The competency questions are used for this purpose.

Step 2: Identify terms and Objects. This stage aims at two goals. The first one is to select the set of vases to study from different museums. That reference set has to represent the domain's richness without being too big (the primary goal of this project is to define the ontology and not to populate it). The second one is to collect the set of terms corresponding to the selected vases. Museum collections, web sites, databases, and books were the sources of information.

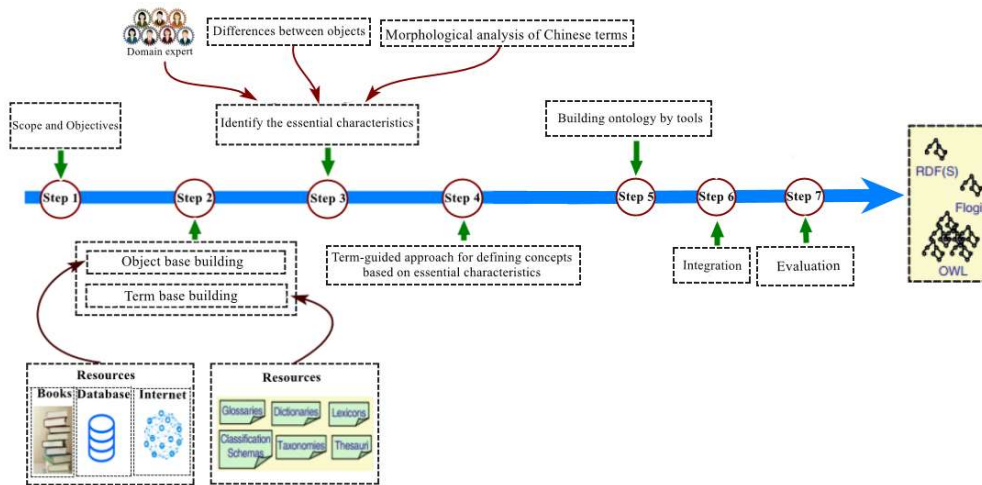


Figure 4. 1. The workflow of term-and-characteristic guided methodology.

Step 3: Identify the essential characteristic. In this step, we need to identify the essential characteristics on which the definition of concepts relies. The method of identifying essential characteristics includes an object point of view and a term point of view, which are presented in chapter 1.3 of this part.

Step 4: A Term-guided approach for defining concepts based on essential characteristics. This approach relies on the fact that a concept is a set of essential characteristics that is stable enough to be named in a given natural language. This step is detailed in chapter 1.4 below.

Step 5: Building ontology by tools. The main work of this step is to translate an ontology in OWL by tools. Chapter implementation will present how to implement a term-and-characteristic guided method on Protégé.

Step 6: Integration. To get more information from other resources and interoperability between different ontologies, integration is significant. We could consider reuse of definitions already built into other ontologies instead of starting from scratch.

Step 7: Evaluation. The evaluation work includes many methods and tools, Such as OOPs, OntoMetrics, and competency questions.

Until now, there are many methodologies for building ontologies. They are related to different activities. Figure 4.2 summarizes the activities proposed by METHONTOLOGY and by Skeletal methodology (Fernández-López et al., 1997). It is almost impossible to take contributions of other methods to propose a general method for building any kind of ontology or meta-ontology. Our methodology is term-and-characteristic guided. In our view, this approach offers two critical advantages: first, concerning representing knowledge, it is more ‘granular’; second, it is user friendly, as it assumes no background in formalizing using restrictions on the part of the ontologist.

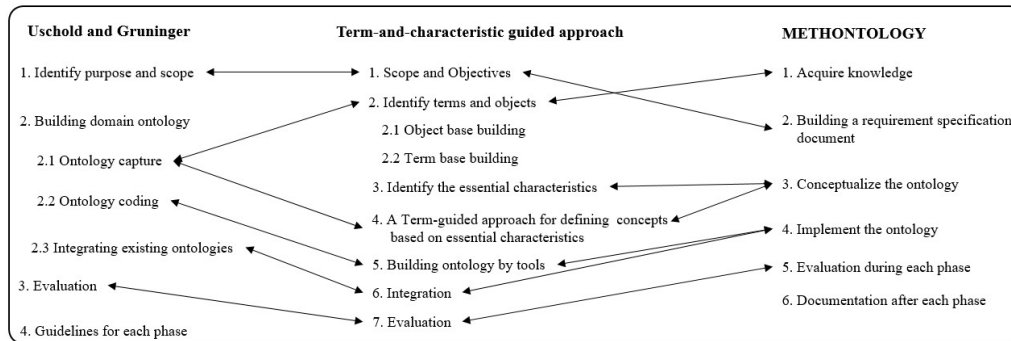


Figure 4. 2. Relationships between these methods.

1.3 Identifying essential characteristic

There are two approaches to identifying essential characteristics. The first one relies on identifying differences between objects, for example, in their structure: vase with or without neck. The second one is based on a morphological analysis of Chinese terms whose characters directly express knowledge of the denoted objects (Wei et al., 2020).

1.3.1 Difference between objects

Identifying differences between objects is a useful means to find out essential characteristics. The differences can be functional (for example, vase for decoration, for storing), material (in clay, in bronze), structural (with or without foot). Thus, one can rely on the part-of relationship between a whole and its parts to understand the concept the object belongs to (Gerstl & Pribbenow, 1996). The presence or the absence of a component can be interpreted as essential characteristics. For example, a Chinese ceramic vase has a lid, a mouth, a neck, handles, shoulder, belly, and foot (Figure 4.30). From the handle point of view, vases can be split into vases with handles and vases without handles corresponding to the essential characteristic /with handle/ and /without handle/ (Wei et al., 2020). The type of vases with handles can be specialized according to the different shapes of handles defining as many as corresponding essential characteristics: /dragon-mask handle/, /dragon-shaped handle/, /elephant-shaped handle/, /fish-shaped handle/, /halberd shaped handle/, /phoenix shaped handle/, /pierced handle/, /ribbon shaped handle/, and /Ru-Yi handle/ (Figure 4.42). These characteristics are exclusive to each other.

1.3.2 Morphological analysis of Chinese terms

The morphological structure of Chinese terms provides important information about nature and the description of the objects denoted by the terms. The Chinese terms of a vase are composed of a set of characters called modifiers whose last one corresponds to the type of vase and the modifiers to either essential or descriptive characteristics. For example, the Nanjing museum adopts the following order of modifiers for naming Tibetan ceramic (霍花, 1989): dynasty + kiln + glaze + color + decoration + shape + texture + type. The information conveyed by the modifiers expresses knowledge of different types, either essential, such as shape, material, and type, or descriptive, like glaze and color. For example, the term “清

雍正粉青釉凸花如意耳蒜头瓷瓶” conveys the essential characteristic shape (“蒜头” garlic-like mouth), material (“瓷”, porcelain), handle (“如意耳”, Ru-Yi handle), and type (“瓶”, vase). It conveys the descriptive characteristics glaze-color (“粉青釉”, powder blue glaze), dynasty (“清”, Qing dynasty), emperor (“雍正”, Yongzheng mark), and decoration (“凸花”, designed with flowers). The English translation of the Chinese ceramic terms used by the Nanjing museum does not follow the Chinese order of modifiers, but the following order: glaze + color + shape + texture + type + decoration + period + kiln. Thus, the previous term “清雍正粉青釉凸花如意耳蒜头瓷瓶” is translated as follows: “powder blue glaze garlic-mouth porcelain vase designed with flowers and Ru-Yi handles, the Yongzheng mark of the Qing dynasty.” (Wei et al., 2020)

1.4 Combining essential characteristic

Let us recall the building concept based on the essential characteristics. From the ISO point of view on terminology, a concept is defined as a unique combination of essential characteristics (ISO 1087-1). Nevertheless, not any combination of essential characteristics defines a meaningful concept from the expert point of view. For the experts, concepts of interest are those that are named in a natural language. Hence, a concept is a set of essential characteristics stable enough to be named in a given language (even if some concepts, without any designation in natural language, can be introduced for organizational purposes of the conceptual system). Terms can then be considered as guidelines for identifying domain concepts to be defined from the expert point of view. For example, the Chinese term “蒜头瓶”, “garlic vase” in English, denotes the following set of essential characteristics {/vase/, /one mouth/, /garlic shape mouth/, /ring foot/}. Based on this formal definition, the natural language definition is then: “Vase with a garlic shaped mouth with a ring foot”. We can notice that the characters “圈足” (“ring foot”) does not appear in the name of the concept (ellipsis) since all types of garlic vases (garlic vase I and garlic vase II) own a ring foot (Wei et al., 2020).

1.5 Implementation

This chapter presents the implementation in Protégé of our ontology building approach. It means how to express in Protégé the notions of terms, concept, object, essential characteristic, descriptive characteristic, and relation. Figure 4.3 shows how these principles are translated into Protégé.

Term: Our approach relies on terms as a starting point in defining domain concepts. In Protégé, terms are in general expressed as labels (using annotated links such as `rdfs:label`). However, terms could be explicitly represented as individuals of a Term class, a subclass of `owl:Thing`. Ontolex-Lemon could also be used to represent a terminology layer above the concept explicitly. We have decided to use the SKOS vocabulary with the properties `skos:prefLabel` for preferred terms and `skos:altLabel` for alternative terms.

Concept: A concept is translated as a named class in Protégé.

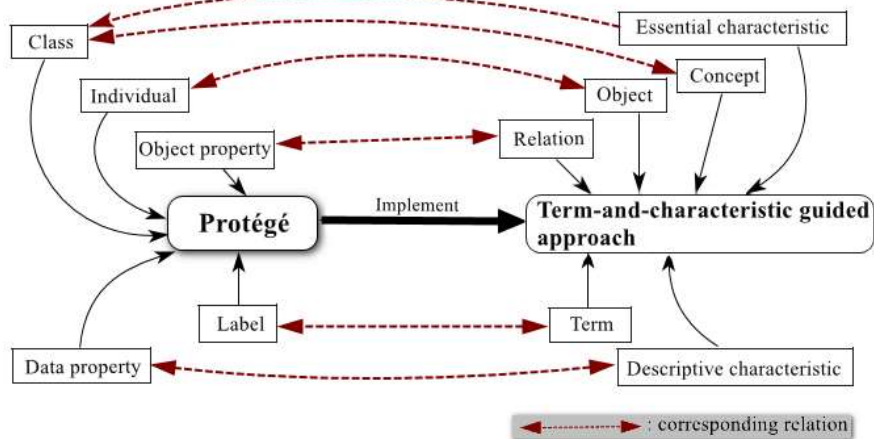


Figure 4. 3. Implementation in Protégé.

Object: Object corresponds to an individual in Protégé.

Essential characteristics: Essential characteristics are translated as classes in Protégé. Although the essential characteristics are the various descriptive “features” (also known variously as “qualities”, “attributes”, “modifiers”) of objects, we need to model them in our ontology. There are two different patterns to represent them in the ontology: 1) as individuals whose enumeration makes up the parent class representing the feature; 2) as disjoint classes which exhaustively partition the parent class representing the feature (Rector, 2005). For example, Figure 4.4 shows the pattern 1, namely, values as sets of individuals.

*In this approach, the class **Health_Value** is considered as the enumeration of the individuals **good_health**, **medium_health**, and **poor_health**. Values are sets of individuals. To say that "John is in good health", is to say that "John has the value **good_health** for **health_status**" This assumes that value is just a unique symbol, and a value set is just a set of such symbols. Normally, the values will need to be asserted to be different from each other. In OWL, any two individuals might represent the same thing unless there is an axiom to say, explicitly, that they are different. In other words, OWL does not make the "Unique Names Assumption". If we did not include the **differentFrom** axiom in the example, then it would be possible that **good_health** and **poor_health** were the same thing, so that it would be possible to have a person who was both in good health and poor health simultaneously. (Rector, 2005).*

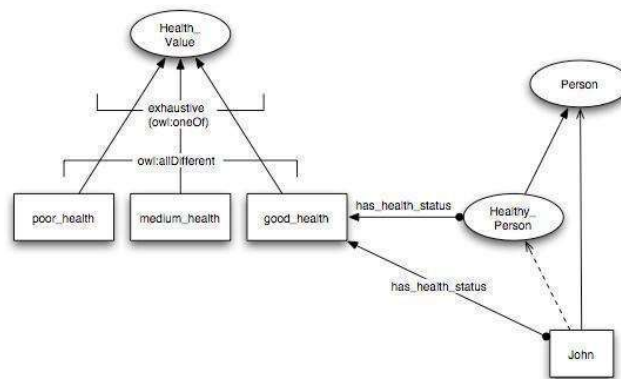


Figure 4. 4. A class-instance diagram of the use of enumerated instances to represent lists of values (Rector, 2005).

The second pattern values as subclasses partitioning a “feature”. In this approach, we consider the feature as a class representing a continuous space that is partitioned by the values in the collection of values. It includes two different variants 1 and variant 2. Figure 4.5 displays variant 1.

To say that "John is in good health" is to say that his health is inside the **Good_health_values** partition of the **Health_value** feature. Theoretically, there is an individual health value, **Johns_health**, but all we know about it is that it lies someplace in the **Good_health_value** partition. The class **Healthy_Person** is the class of all those persons who have health in the **Good_health_value** partition. (Rector, 2005)

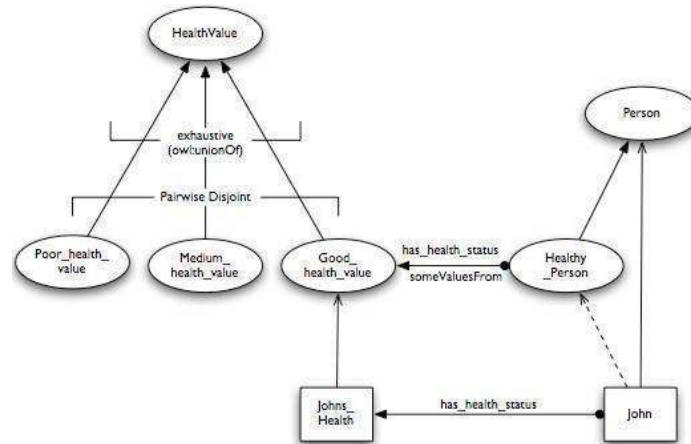


Figure 4. 5. A class-instance diagram of the use of partitioning classes for collections of values (Rector, 2005).

In variant 1, the individual **Johns_Health** is explicitly represented, while an existential restriction in variant 2 implies it. Figure 4.6 shows the variant 2.

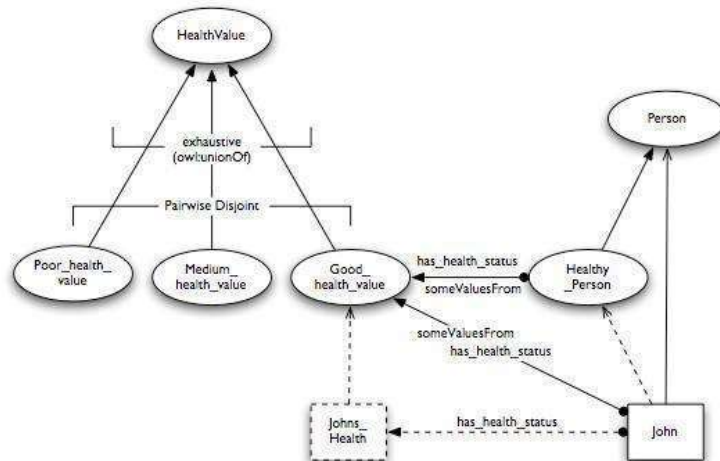


Figure 4. 6. Pattern 2 variant 2 with an anonymous individual for John's Health (Rector, 2005).

Compared with pattern 1, we prefer to choose pattern 2 in our work. Because the pattern 1 is no possibility of further sub-partitioning of values and no way to represent alternative partitionings of the same feature space, which causes the reasoner to perform all the expected inferences reliably (Rector, 2005). Pattern 2 allows values to be further sub-partitioned and has several alternative partitionings of the same feature space.

The result is in OWL-DL and classifies correctly using either FaCT or Racer - and almost certainly any other reasoner that handles any reasonable subset of OWL-DL (Rector, 2005). In pattern 2, we prefer to choose the variant 2 in our work. Because we do not need to define the individuals of “features” in ontology, it reduces the complexities of the ontology and develops an ontology. Therefore, in our work, we select the variant 2 of pattern 2 to model the essential characteristics, which are expressed as classes.

Descriptive characteristics: Descriptive characteristics are attributes whose values describe the current state of an object. Descriptive characteristics are translated either as data properties if their value is a data literal or as object properties and classes if the value is an individual. For example, the decoration characteristic is represented by the data property ‘isDecoratedBy’, whose domain is the Vessel class, and the range is the String data type. The dynasty to which a vase belongs is represented by the object property ‘hasDynasty’ whose domain is the Vessel class, and the range is the Dynasty class. Using object properties rather than data properties for representing some descriptive characteristics allows linking the ontology to external resources, including AAT and CIDOC CRM.

Relation: Relations, e.g. ‘hasFunction’, ‘hasComponent’, ‘isMadeOf’, are represented as object properties. For example, the object property ‘isMadeOf’ whose domain is the Vessel class and range is the Material Class, and the object property ‘hasComponent’ whose domain is the Vessel class and range is the Component class. Let us note that among the different types of ‘part-of’ relationships, only the ‘Component/Integral Object’ relationship has been taken into account (Winston et al., 1987).

Chapter 2. TAO CI Ontology Authoring

2.1 Objectives

The TAO ontology presented in this article aims at:

- 1) Providing a knowledge representation of Chinese ceramic of the Ming and Qing dynasties in a domain ontology form.
- 2) Publishing, opening, and linking it to the LOD.
- 3) Building a multilingual e-dictionary of ceramic vases based on the Tao Ci ontology.
- 4) Proposing a method for translating essential characteristics into Protégé.

2.2 Competency questions

Competency questions are questions that an ontology must be able to answer expressed in natural language. They often could be regarded as a functional requirement that must be satisfied by the ontology (Ren et al., 2014). Table 4 shows the competency questions and objectives of the Tao Ci ontology.

Table 4. The competency questions (variables start by a question mark, references to individuals by the indefinite article).

CQ	Competency Question	Class(es)	Relation
1	What are the different types of vases?	Vase	?vase <i>is-a</i> Vase
2	What material the vase is made of?	Vase, Material	aVase <i>isMadeOf</i> ?material
3	What is the glaze color of the vase?	Vase, GlazeColor	aVase <i>hasGlazeColor</i> ?glazecolor
4	Which dynasty is the vase?	Vase, Dynasty	aVase <i>hasDynasty</i> ?dynasty
5	Which emperor is the vase?	Vase, Emperor	aVase <i>hasEmperor</i> ?emperor
6	What are the Chinese and English terms of vases?	Vase	?vase <i>label</i> ?string
7	Which temperature was the vase fired at?	Vase, Temperature	aVase <i>isFiredAt</i> ?temperature
8	What are the components of a vase?	Vase, Component	aVase <i>hasComponent</i> ?component
9	What is the function of a vase?	Vase, Function	aVase <i>hasFunction</i> ?function
10	Which Dynasty does an Emperor belong to?	Emperor, Dynasty	aEmperor <i>belongTo</i> ?dynasty
11	What is the foot diameter of a vase?	Vase	aVase <i>diameterOfFoot</i> ?string
12	What is the height of a vase?	Vase	aVase <i>height</i> ?string
13	Which collection does a vase belong to?	Vase	aVase <i>collectedIn</i> ?string
14	Which kiln produced a vase?	Vase	aVase <i>producedIn</i> ?string
15	What is the decoration of a vase?	Vase	aVase <i>decoratedBy</i> ?string
16	What are the images of a vase?	Vase	aVase <i>image</i> ?string
17	What is the definition of a vase?	Vase	aVase <i>definition</i> ?string

2.3 Collection of research objects

The first step of our work was to select the set of vases to study. The set had to be enough representative of the domain's richness without being too big since the main and first goal was defining the ontology rather than populating it. In China, many museums publish much information about ceramic vessels on their websites. One hundred forty-nine objects were selected from different museums in China. Ninety-seven objects come from the Palace Museum⁸⁹ that has the most important collection of ceramics; Twenty-two objects come from the National Museum of China⁹⁰; Twenty-four objects are from the Guangdong

⁸⁹ <https://www.dpm.org.cn/Home.html>

⁹⁰ <http://www.chnmuseum.cn/>

Museum⁹¹. Four objects come from the Shanghai Museum⁹², and two objects are from the Capital Museum⁹³. For the selection of objects, we have adopted the following four criteria. The two first concerns the selection of the museum, which had to fulfill the following conditions: first, the collection of ceramics had to be recognized as a reference in ceramic vessels in China; second, the information about the collection should be publicly available and precise enough for the building of an ontology. The third principle was to select objects as different as possible, i.e., of different types according to their shape, the technique of making, decoration. The fourth principle was to have at least three examples as diverse as possible, for instance, in their shape, but belonging to the same type of vases, i.e., olive-shaped vase, arrow vase.

2.4 Linguistic Dimension: identifying term

Although our work focuses on Chinese ceramic vases, to expand in the future, our work includes two parts: the ceramic vessel model and the ceramic vase model. There is an essential fact that the term is from archaeology books and Chinese museums. The Chinese terms are drawn from the Chinese book: 中国古陶瓷图典⁹⁴. English terms are from the book: A Chinese-English Glossary of cultural relics and archaeology⁹⁵. The Chinese museums include the Palace Museum⁹⁶, the National Museum of China⁹⁷, and the Nanjing Museum⁹⁸. The work of identifying the terms (names) contains two parts: identifying terms of vessels and identifying terms of vases. The language will be in Chinese and English that is to communicate with the world.

2.4.1 Identifying terms (names) of vessels

All vessel terms are in table 5. Terms include the preferred term and alternative term. The preferred term is represented in prefLabel; The alternative term is represented in altLabel.

Table 5. The terms correspond to the vessels.

Term				Example of object
English		Chinese		
prefLabel	altLabel	prefLabel	altLabel	
vase	bottle	瓶	花瓶	Figure 4.7.a
zun		尊		Figure 4.7.b

⁹¹ <http://www.gdmuseum.com/>

⁹² <https://www.shanghaimuseum.net/museum/frontend/>

⁹³ <http://www.capitalmuseum.org.cn/>

⁹⁴ 中国古陶瓷图典 translated in “Atlas of ancient Chinese ceramics”, ISBN is the 7501009244. The author is Xianming Feng who was a famous archaeologist.

⁹⁵ Chinese name of this book is “汉英文物考古词汇”. The ISBN is the 7-80047-510-7. The author is Dianming Wang.

⁹⁶ <https://www.dpm.org.cn/Home.html>

⁹⁷ <http://www.chnmuseum.cn/>

⁹⁸ <http://www.njmmuseum.com/zh>

cup		杯		Figure 4.7.c
snuff bottle		鼻烟壶		Figure 4.7.d
basin		盆		Figure 4.8.a
bo		钵		Figure 4.8.b
dish	plate	盘	碟子	Figure 4.8.c
bowl		碗		Figure 4.8.d
jue		爵		Figure 4.8.e
gu		觚		Figure 4.9.a
jug	pot	壶		Figure 4.9.b
censer		炉		Figure 4.9.c
box		盒		Figure 4.9.d
jar		罐		Figure 4.9.e



Figure 4. 7. Identifying vessel terms denote objects.



Figure 4. 8. Identifying vessel terms denote objects.



Figure 4. 9. Identifying vessel terms denote objects.

2.4.2 Identifying terms (names) of vases

The primary work of this thesis focuses on Chinese ceramic vases. The building ontology of Chinese ceramic vases is based on the terms of Chinese ceramic vases. Therefore, this chapter will identify terms. Figure 4.10 shows that some terms are derived from the books 《汉英文物考古词汇》 (A Chinese-English Glossary of Cultural Relics and Archaeology) and 《A Glossary of Chinese Art and Archaeology》 .

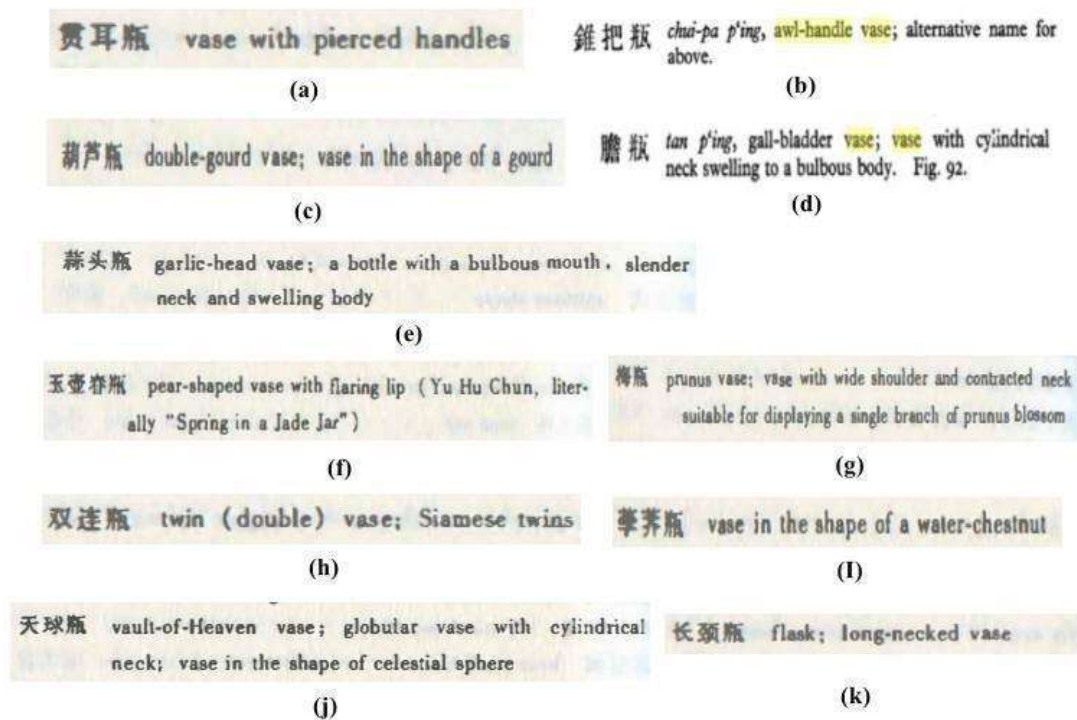


Figure 4. 10. Some terms are derived from books.

Table 6 shows the terms corresponding to vases in English and Chinese. The term also includes the preferred term represented prefLabel and the alternative term referred to as altLabel. The caption indicates the textual source of the English terms.



Figure 4. 11. The terms correspond to vases.

Table 6. Identifying terms corresponding to vases.

Term				Text for terms	Example of object
English		Chinese			
prefLabel	altLabel	prefLabel	altLabel		
arrow vase ⁹⁹		贯耳瓶		Figure 4.10.a	
arrow vase I		贯耳瓶 I			Figure 4.11.a
arrow vase II		贯耳瓶 II			Figure 4.11.b
arrow vase III		贯耳瓶 III			Figure 4.11.c
awl-handle vase		锥把瓶		Figure 4.10.b	Figure 4.11.d
rouleau vase ¹⁰⁰		软棒槌瓶			Figure 4.12.a
cong-shaped vase ¹⁰¹		琮式瓶			Figure 4.12.b
elephant leg vase ¹⁰²		象腿瓶			Figure 4.12.c
double-tube vase ¹⁰³		多管瓶			Figure 4.12.d
double-gourd vase		葫芦瓶		Figure 4.10.c	
double-gourd vase I		葫芦瓶 I			Figure 4.13.a
double-gourd vase II		葫芦瓶 II			Figure 4.13.b

⁹⁹ <https://art.thewalters.org/detail/26828/arrow-vase/>

¹⁰⁰ <https://www.brooklynmuseum.org/opencollection/objects/3310>

¹⁰¹ <http://collection.imamuseum.org/artwork/56447/>

¹⁰² <https://www.pinterest.fr/pin/546765211010136237/>

¹⁰³ <https://www.emissaryusa.com/double-gourd-vase-8419.html>

double-gourd vase III		葫芦瓶 III			Figure 4.13.c
lantern-shaped vase ¹⁰⁴		灯笼瓶			Figure 4.13.d
gall-bladder vase		胆式瓶		Figure 4.10.d	
gall-bladder vase I		胆式瓶 I			Figure 4.14.a
gall-bladder vase II		胆式瓶 II			Figure 4.14.b
garlic-head vase		蒜头瓶		Figure 4.10.e	
garlic-head vase I		蒜头瓶 I			Figure 4.14.c
garlic-head vase II		蒜头瓶 II			Figure 4.14.d
loosing ring vase ¹⁰⁵		活环瓶			Figure 4.15.a
willow-leaf-shaped vase ¹⁰⁶		柳叶瓶			Figure 4.15.b
oil-hammer vase ¹⁰⁷		油锤瓶			Figure 4.15.c
pear shaped vase	bottle vase	玉壶春瓶		Figure 4.10.f	Figure 4.15.d
olive-shaped vase ¹⁰⁸		橄榄瓶			
olive-shaped vase I		橄榄瓶 I			Figure 4.16.a
olive-shaped vase II		橄榄瓶 II			Figure 4.16.b
plum vase ¹⁰⁹		梅瓶		Figure 4.10.g	
plum vase I		梅瓶 I			Figure 4.16.c
plum vase II		梅瓶 II			Figure 4.16.d
reward vase ¹¹⁰		赏瓶			Figure 4.17.a
square rouleau vase ¹¹¹		方棒槌瓶			Figure 4.17.b
twin vase		双联瓶		Figure 4.10.h	Figure 4.17.c

¹⁰⁴ <https://www.pinterest.fr/pin/198439927318438545/>

¹⁰⁵ <https://www.artfoxlive.com/product/234983.html>

¹⁰⁶ <http://collection.imamuseum.org/artwork/33502/>

¹⁰⁷ http://www.artmuseum.tsinghua.edu.cn/en/cpsj_english/gndc/gexy/201605/t20160531_1228.shtml

¹⁰⁸ <https://www.pinterest.fr/pin/546765211012039620/>

¹⁰⁹ <https://en.wikipedia.org/wiki/Meiping>

¹¹⁰ <https://www.invaluable.com/auction-lot/qing-famille-rose-phoenix-reward-vase-148-c-6e24b17b90>

¹¹¹ <http://www.alaintruong.com/archives/2019/02/25/37130282.html>

water-chestnut vase		荸荠瓶		Figure 4.10.I	Figure 4.17.d
vault-of-heaven vase		天球瓶		Figure 4.10.j	
vault-of-heaven vase I		天球瓶 I			Figure 4.18.a
vault-of-heaven vase II		天球瓶 II			Figure 4.18.b
flower-mouth vase ¹¹²		花口瓶			
flower-mouth vase I		花口瓶 I			Figure 4.18.c
flower-mouth vase II		花口瓶 II			Figure 4.18.d
long-necked vase		长颈瓶		Figure 4.10.k	Figure 4.19.a
moon shaped vase ¹¹³	moon flask	宝月瓶	抱月瓶		Figure 4.19.b

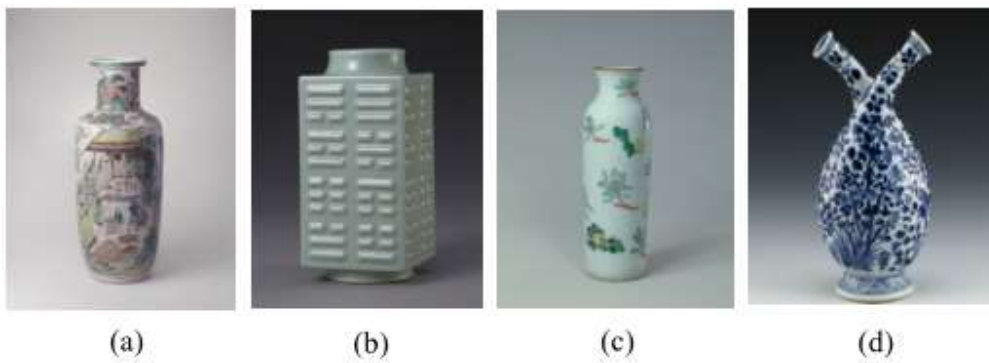


Figure 4. 12. The terms correspond to vases.



Figure 4. 13. The terms correspond to vases.

¹¹² https://www.liveauctioneers.com/item/75391920_a-chinese-white-glazed-flower-mouth-vase-later-qing

¹¹³ <https://www.pinterest.fr/jfaxford/moon-flasks/>

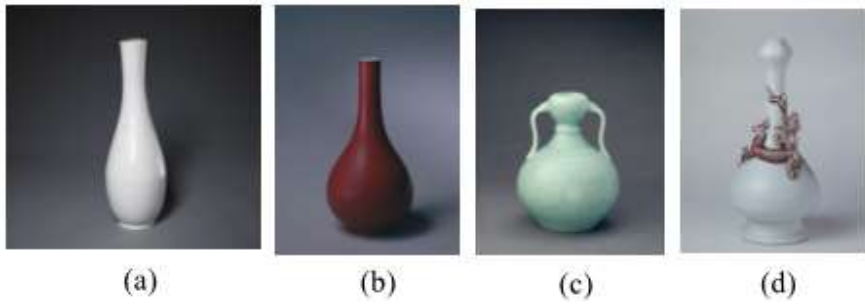


Figure 4. 14. The terms correspond to vases.

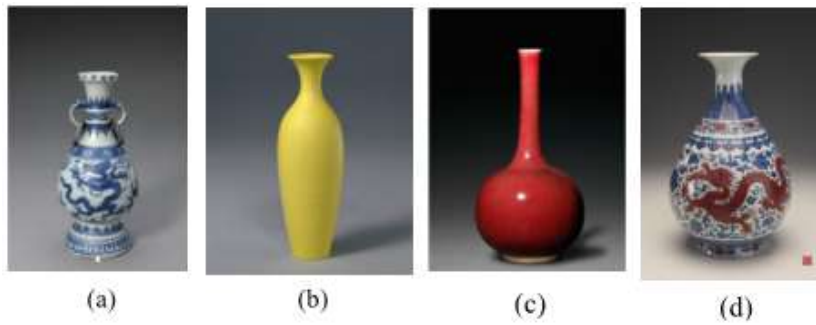


Figure 4. 15. The terms correspond to vases.



Figure 4. 16. The terms correspond to vases.



Figure 4. 17. The terms correspond to vases.



Figure 4. 18. The terms correspond to vases.



Figure 4. 19. The terms correspond to vases.

2.5 Conceptual Dimension: identifying essential characteristic

2.5.1 Essential characteristics: Vessel

Recall methods of identifying essential characteristics that include object point of view and terms point of view. The object point of view is to find the differences between objects. The difference could be material, function, and structure.

The part-whole relations play a vital role in knowledge processing and natural language semantics. A taxonomy of part-whole or meronymic relation includes six types: 1) component-integral object (pedal-bike), 2) member-collection (ship-fleet), 3) portion-mass (slice-pie), 4) stuff-object (steel-car), 5) feature-activity (paying-shopping), and 6) place-area (Everglades-Florida) (Winston et al., 1987). The differences among the six types of meronymic relations are indicated by the values of three relation elements that summarize the relations' characteristic properties. Meronymic relations differ in three ways: whether the relation of part to the whole is functional or not, whether the parts are homogenous or not, and whether the part and whole are separable or not (Winston et al., 1987). Figure 4.20 shows the distinction between the six types.

Six Types of Meronymic Relations with Relation Elements

Relation	Examples	Relation Elements		
		Functional	Homeomerous	Separable
Component/ Integral Object	handle-cup punchline-joke	+	-	+
Member/ Collection	tree-forest card-deck	-	-	+
Portion/Mass	slice-pie grain-salt	-	+	+
Stuff/Object	gin-martini steel-bike	-	-	-
Feature/Activity	paying-shopping dating-adolescence	+	-	-
Place/Area	Everglades-Florida oasis-desert	-	+	-

Functional (+)/Nonfunctional (-): Parts are/are not in a specific spatial/temporal position with respect to each other which supports their functional role with respect to the whole.

Homeomerous (+)/Nonhomeomerous (-): Parts are similar/dissimilar to each other and to the whole to which they belong.

Separable (+)/Inseparable (-): Parts can/cannot be physically disconnected, in principle, from the whole to which they are connected.

Figure 4. 20. The distinction between the six types (Winston et al., 1987).

The components and portions are vital to our work. An entity that is viewed as heterogeneously structured is partitioned into Components (Gerstl & Pribbenow, 1996). Each component is different from each other, but it must be an essential part of the whole. Portions are maximal parts with a particular intrinsic property defined by an external criterion (Gerstl & Pribbenow, 1996). Portions are constructed by using a property dimension to choose parts. At the beginning of this work, we partition the vessel into different components based on part-whole relations' conceptual theory. The structure is portioned into seven parts (Figure 4.21). Compared with each component between different objects, we could find differences and identify the essential characteristics.

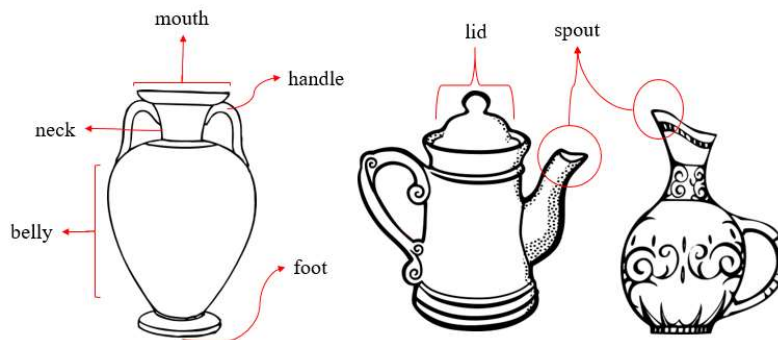


Figure 4. 21. The components of vessels.

Recall the term point of view that is the morphological analysis of Chinese terms. The morphological structure of Chinese terms provides essential information on the nature of the objects they are named. Therefore, it helped us to identify possible essential and descriptive characteristics. For example, the term “清雍正粉青釉凸花如意耳蒜头瓷瓶” is translated as follows: “powder blue glaze garlic porcelain vase designed with flowers and Ru-Yi handles, the Yongzheng mark of the Qing dynasty.” It conveys the essential characteristic shape (“蒜头”, garlic-like mouth), material (“瓷”, porcelain), handle (“如意耳”, Ru-Yi handle), and type (“瓶”, vase). It conveys the descriptive characteristic glaze and color (“粉青釉”, powder blue glaze), dynasty (“清”, Qing dynasty), emperor (“雍正”, Yongzheng mark), and decoration (“凸花”, designed with flowers).

2.5.1.1 Material

There are many vessels made in different materials. The material is an important characteristic of vessels. So the material is viewed as the axis of analysis. The essential characteristics of material include /bronze/, /clay/, /glass/, /gold/, /silver/, /jade/, and /wood/ (Figure 4.22). The material could make different vessels under different temperatures, such as ceramic. Therefore, the temperature also is an axis of analysis. The essential characteristics of temperature include /high temperature/ and /low temperature/. For ceramic vessels, the high temperature was more than 1200°C, whereas the low temperature was less than 1200°C.

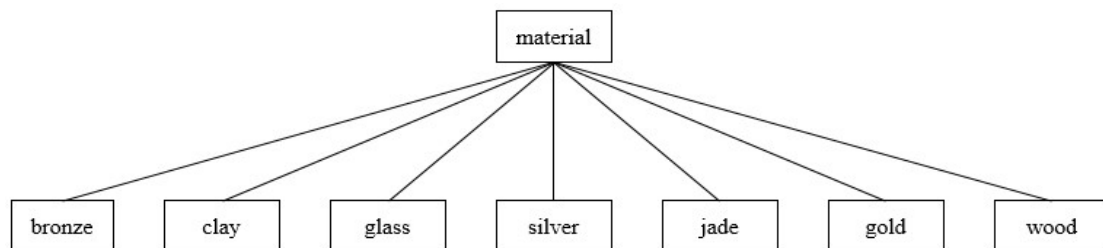


Figure 4. 22. The essential characteristics of the material analysis axis.

2.5.1.2 Function

Function is an important characteristic for vessels. From the function view, the vessel could be used for different purposes. Therefore, the essential characteristics of function include /for storing liquid/, /for storing solid/, /for snuff/, /for decoration/, /for drinking/, /for cooking/, /for eating/, /for washing/, and /for sacrifice/ (Figure 4.23).

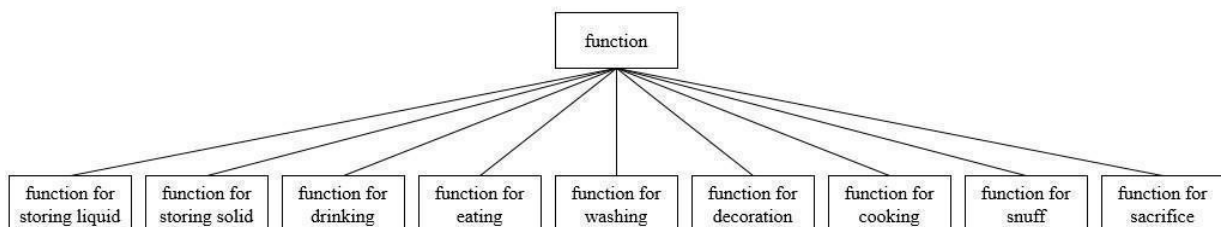


Figure 4. 23. The essential characteristics of the function analysis axis.

These essential characteristics are easy to understand. For example, /for storing liquid/ refers to the vessel is used for storing liquid. The /for snuff/ refers to the vessel used to snuff in the ancient.

2.5.1.3 Structure

According to the theory of part-whole relation, the vessel could be decomposed into these components: mouth, neck, handle, belly, foot, and spout (Figure 4.21).

The component of mouth includes two essential characteristics: /open mouth/ and /convergence mouth/. These characteristics refer to the shape of the rim of the mouth. The open mouth is gradually widened and spacious near to the rim of the mouth. The convergence mouth is gradually converging inward at the rim of the mouth (Figure 4.24).

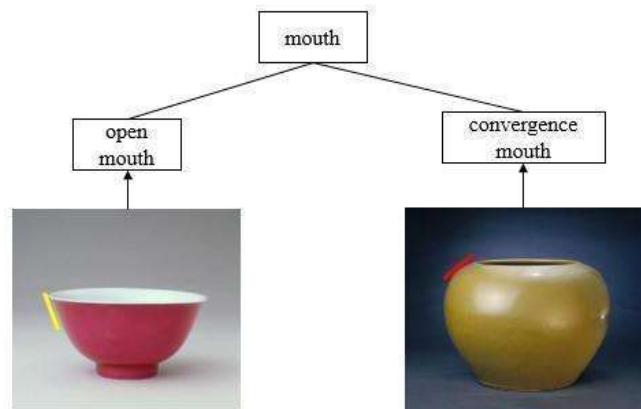


Figure 4. 24. The essential characteristic of the mouth component.

The component of neck includes the essential characteristics: /with neck/, /without neck/, /wide neck/, and /narrow neck/ (Figure 4.25). The neck is between the rim of the mouth and shoulder, like the human's neck. The /with neck/ refers to the vessel with a neck. The /without neck/ refers to the vessel does not have a neck. The /with neck/ and /without neck/ could not appear in one object at the same time. The /wide neck/ and /narrow neck/ are in the same axis of analysis and could not exist in one object at the same time. However, these two essential characteristics are dependent on the /with neck/.

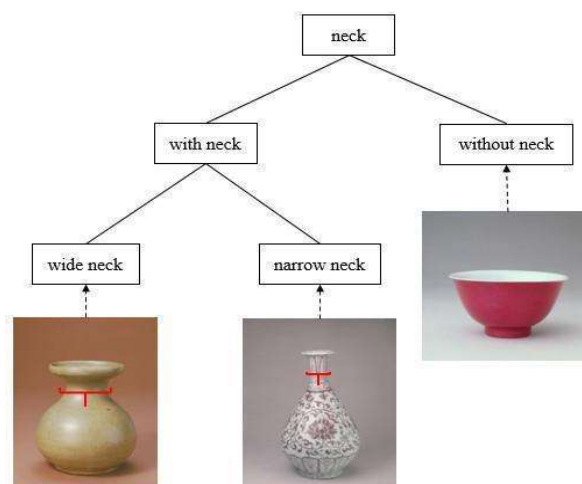


Figure 4. 25. The essential characteristics of the neck component.

The belly is the main middle space of the vessel for storing things. The belly component includes two essential characteristics: /deep belly/ and /shallow belly/ (Figure 4.26). The deep belly describes the belly of vessels high. The shallow belly describes the belly of vessels that are low.

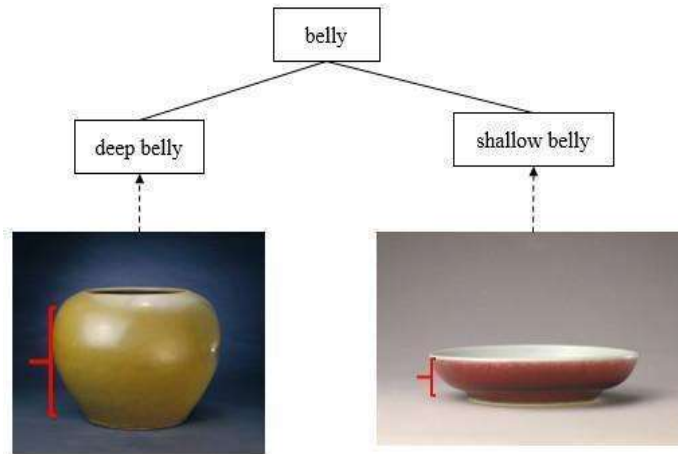


Figure 4. 26. The essential characteristic of the belly component.

The foot component includes four essential characteristics: /with foot/, /without foot/, /high foot/, and /low foot/ (Figure 4.27). The essential characteristics could not appear in one object at the same time under the same axis of analysis. The foot is under the vessel and supports the vessel, like legs. The high foot is usually used to describe the foot. The low foot is used to describe the foot. The /high foot/ and /low foot/ depend on the /with foot/.

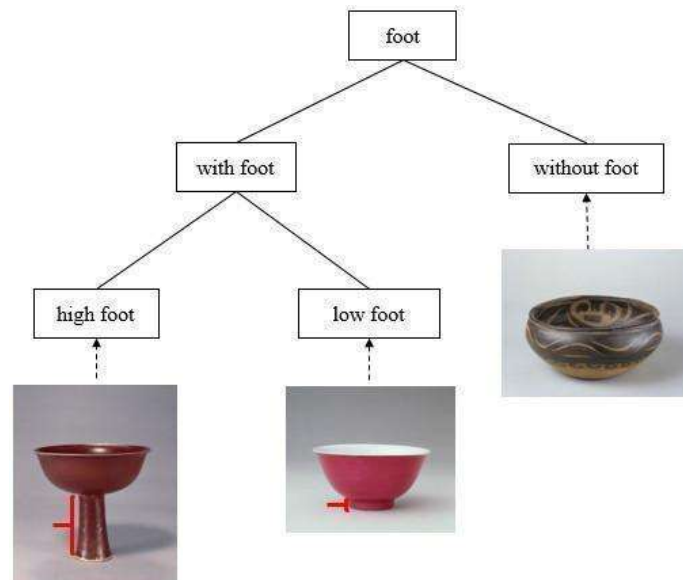


Figure 4. 27. The essential characteristics of foot.

The spout is also called “mouth.” It is used to pour the liquid for storing liquid vessels. It is divided into two kinds. The first one is located in the mouth; The second one is located in the belly like a tube. The spout component includes two essential characteristics: /with spout/ and /without spout/ (Figure 4.28).

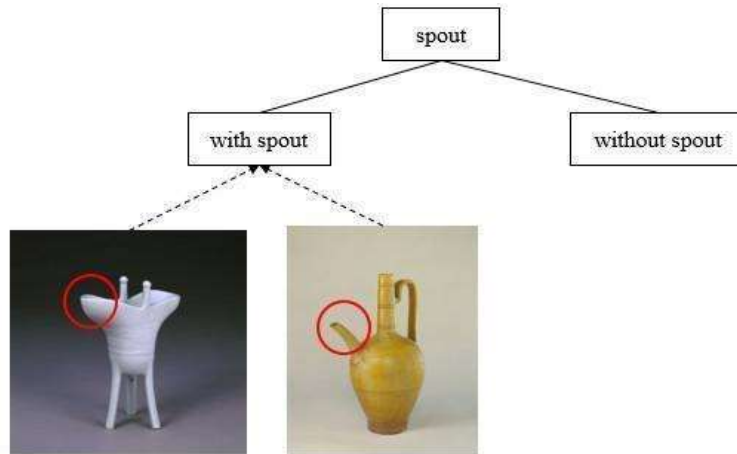


Figure 4. 28. The essential characteristics of the spout component.

The shape of the body refers to the shape of the vessel. It has two essential characteristics: /trumpet shaped/ and /not trumpet shaped/ (Figure 4.29). The /trumpet shape/ refers to the vessel shape like a trumpet. The /not trumpet shaped/ refers to the vessel shape does not like a trumpet.

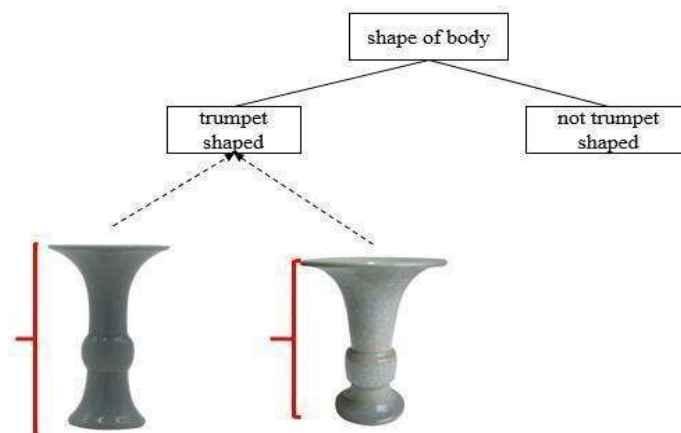


Figure 4. 29. The essential characteristics of body shape.

2.5.2 Essential characteristics: Vase

In the previous chapter, we have analyzed the essential characteristics of vessels. This section will present the essential characteristics of vases. Depending on the firing temperature, the ceramic vessels are divided into pottery and porcelain. The pottery was fired at low temperatures (1000°C-1200°C), and the porcelain was fired at high temperatures (1200°C - 1300°C). The porcelain vessels can be of different types, such as bowl, cup, dish, and vase. In this thesis, the domain of building ontology will focus only on Chinese

porcelain vases defined as “clay vessels fired at the high temperature and used for decoration.” Therefore, the essential characteristics of vases only focus on the structure of vases.

2.5.2.1 Structure

According to the conceptual theory of part-whole relations, a vase could be partitioned into a lid, mouth, neck, shoulder, handle, ring, belly, bottom, and foot component (Figure 4.30).

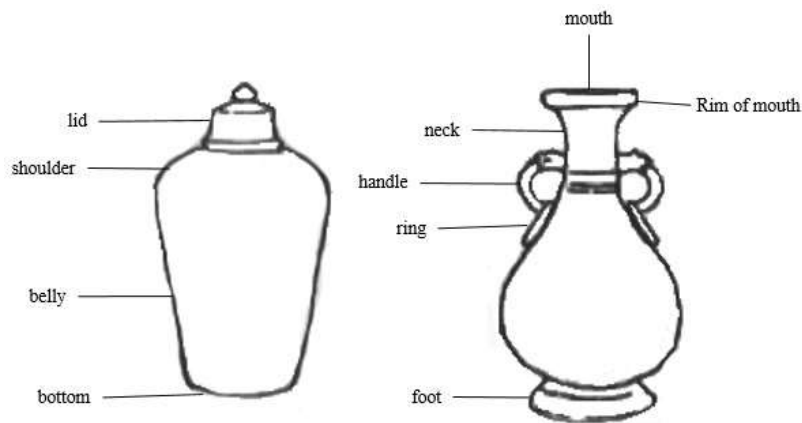


Figure 4. 30. The components of the vase.

Lid

The lid component has two essential characteristics: /with lid/ and /without lid/ (Figure 4.31). A lid is a cover on a vessel that could be lifted or removed. The /with lid/ represents the vessel has the lid. The /without lid/ represents the vessel does not have the lid.

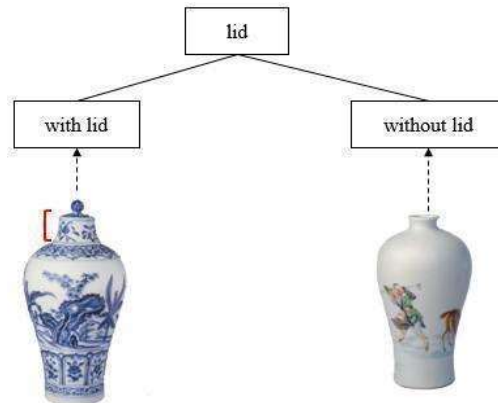


Figure 4. 31. The essential characteristics of the lid component.

Mouth

The mouth component includes several axes of analysis: number of mouths, size of mouth, mouth rim, a wall of mouth, top view of mouths, and the whole shape of mouths. Each analysis axis includes the essential characteristics.

The first axis of analysis is about the number of mouths, either one or several. It includes two essential characteristics: /one mouth/ and /multi-mouths/ (Figure 4.32). “First” axis in the sense that all other characteristics depend on the number of mouths¹¹⁴. In our case, they are only applicable to one-mouth vases.

The analysis axis of the size of mouths includes two essential characteristics: /large mouth/ and /small mouth/ (Figure 4.33). There is no standard value to distinguish the mouth between a large mouth or a small one. The analysis axis of the mouth rim has two essential characteristics: /lip mouth/ and /everted-rim mouth/ (Figure 4.34). The /lip mouth/ refers to a thick edge is raised on the edge of mouths, and the lines are round like lips. The /everted-rim mouth/ refers to roll outward at the mouth edge. The analysis axis of the wall of mouths has two essential characteristics: /straight mouth/ and /outward mouth/ (Figure 4.35). The /outward mouth/ refers to the mouth wall is in a circular arc shape and upward to the edge of the mouth, which is in the shape of a trumpet. The /straight mouth/ means that the mouth wall is straight without bending.

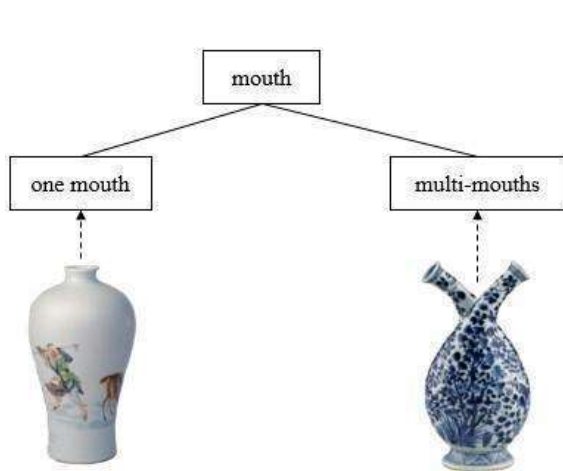


Figure 4. 32.The essential characteristics of mouth size.

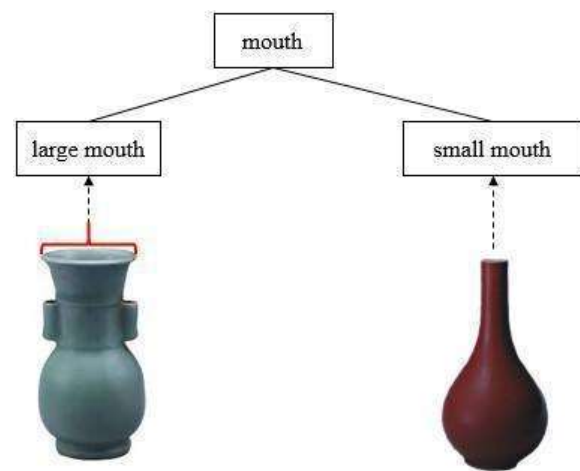


Figure 4. 33. The essential characteristic of mouth quantity.

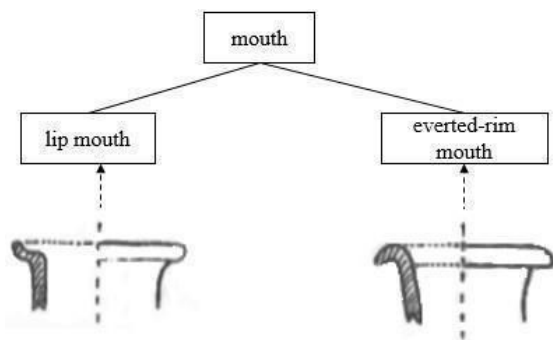


Figure 4. 34. The essential characteristics of the mouth rim.

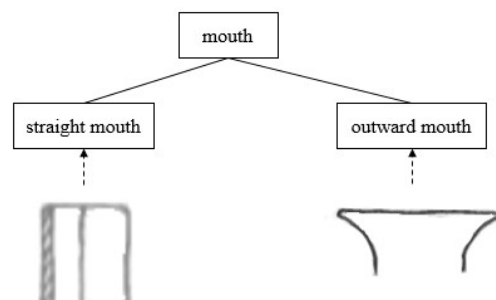


Figure 4. 35. The essential characteristics of the wall of the mouth.

The analysis axis of the top view of the mouth includes two essential characteristics: /square mouth/ and /circle mouth/ (Figure 4.36). The /square mouth/ means the top view of the mouth is square. The /circle mouth/ means the top view of the mouth is a circle. The analysis axis of the whole shape of the mouth

¹¹⁴ That corresponds to “dependent characteristics” (Felber 1984), a useful notion for building conceptualization. Unfortunately, this notion has not been included in the ISO standards on Terminology.

includes five essential characteristics: /brush washer shaped mouth/, /flower shaped mouth/, /garlic shaped mouth/, /plate shaped mouth/, and /trumpet shaped mouth/ (Figure 4.37). The /brush washer shaped mouth/ means the mouth shape looks like a brush washer that was a utensil for washing writing brush with water in Chinese ancient. The /flower shaped mouth/ refers to the mouth that looks like a flower. The /garlic shaped mouth/ means the shape of the mouth likes garlic. The /plate shape mouth/ means the shape of the mouth is similar to the plate shape. The /trumpet shaped mouth/ is that the mouth shape likes a trumpet.

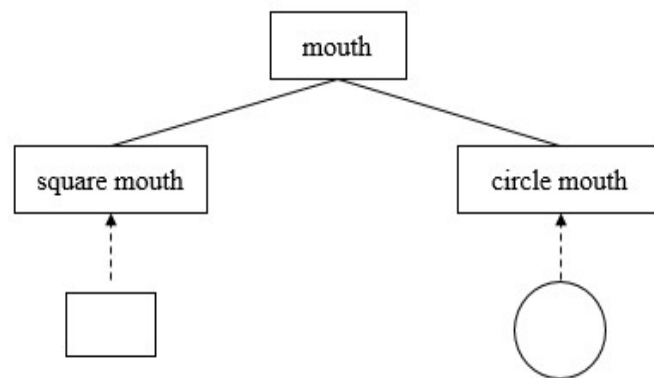


Figure 4. 36. The essential characteristics of the top of view of the mouth.

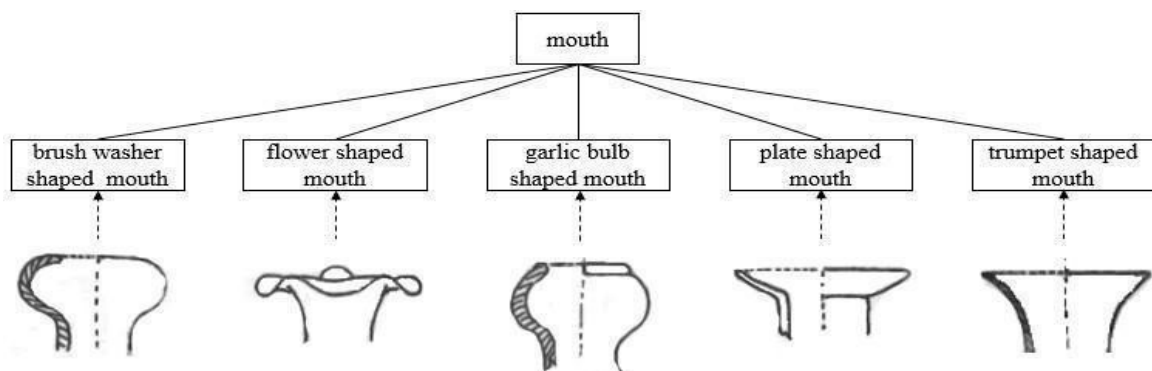


Figure 4. 37. The essential characteristics of the whole shape of the mouth.

Neck

The neck is part of a hollow object at the top and is narrower than the part below it and is usually between the mouth and shoulder. The neck component includes three axes of analysis: neck length, neck width, and bending degree of the neck. The analysis axis of the neck length has two essential characteristics: /long neck/ and /short neck/ (Figure 4.38). The analysis axis of the width of the neck includes two essential characteristics: /wider neck/ and /slender neck/ (Figure 4.39). The analysis axis of the bending degree of the neck has two essential characteristics: /straight neck/ and /not straight neck/ (Figure 4.40).

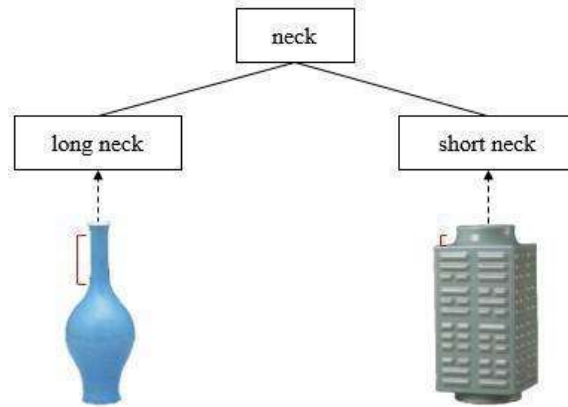


Figure 4. 38. The essential characteristics of the length of the neck.

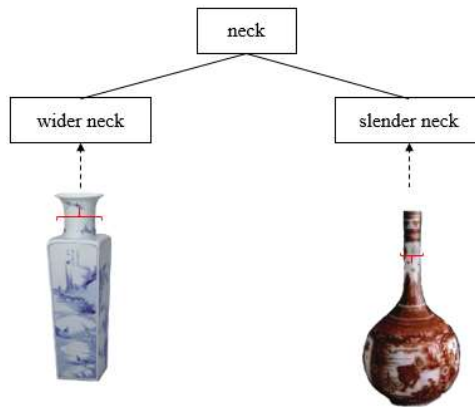


Figure 4. 39. The essential characteristics of the width of the neck.

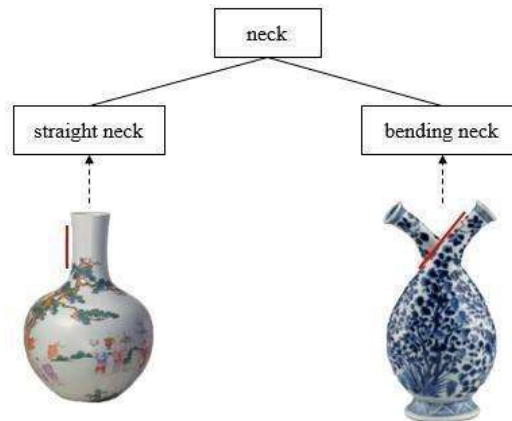


Figure 4. 40. The essential characteristics of a bending degree of the neck.

Shoulder

The shoulder is the part of the vase that curves out below its opening. The shoulder component has four essential characteristics: /flat shoulder/, /folding shoulder/, /circle shoulder/, and /slanting shoulder/ (Figure 4.41).

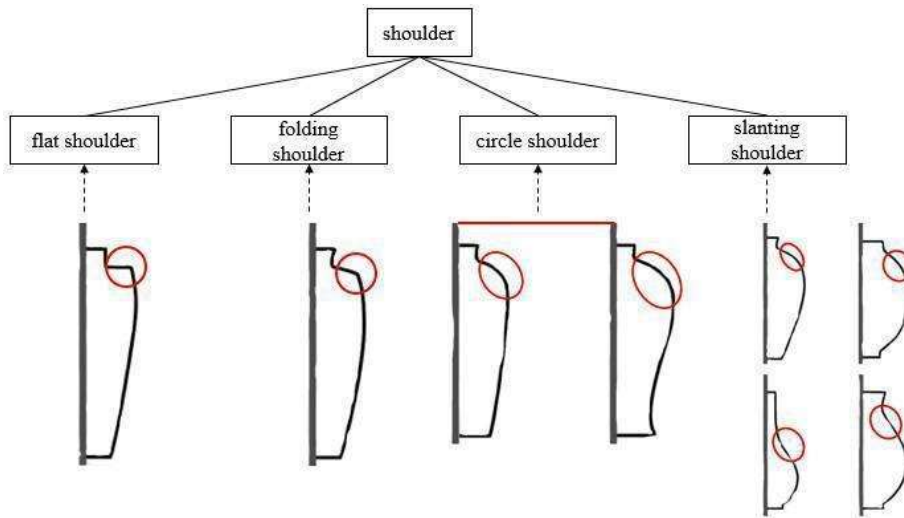


Figure 4. 41. The essential characteristics of the shoulder.

Handle

The handle is a part of an object designed for holding, moving, or carrying the object easily. However, it is used for decoration in Chinese ceramic vases. The handle component includes ten essential characteristics according to their shape: /dragon-head handle/, /dragon-shaped handle/, /tiger-head handle/, /elephant-head handle/, /fish-shaped handle/, /halberd shaped handle/, /phoenix shaped handle/, /pierced handle/, /ribbon shaped handle/, and /ru-yi handle/ (Figure 4.42). The /dragon-head handle/ means the handle is in the shape of the dragon-head. The /dragon-shaped handle/ refers to the handle is in the shape of a dragon. The /elephant-head handle/ means the handle is in the shape of an elephant-head. The /fish-shaped handle/ is the handle that looks like a fish. The /tiger-head handle/ is the handle is in the shape of a tiger-head. The /halberd shaped handle/ is the handle looks like a halberd. The /phoenix shaped handle/ refers to the handle is in the shape of a phoenix. The /pierced handle/ means the handle looks like a pierced. The /ribbon shaped handle/ means the handle is in the shape of the ribbon. The /ru-yi handle/ means the handle is in the shape of Ru-Yi.

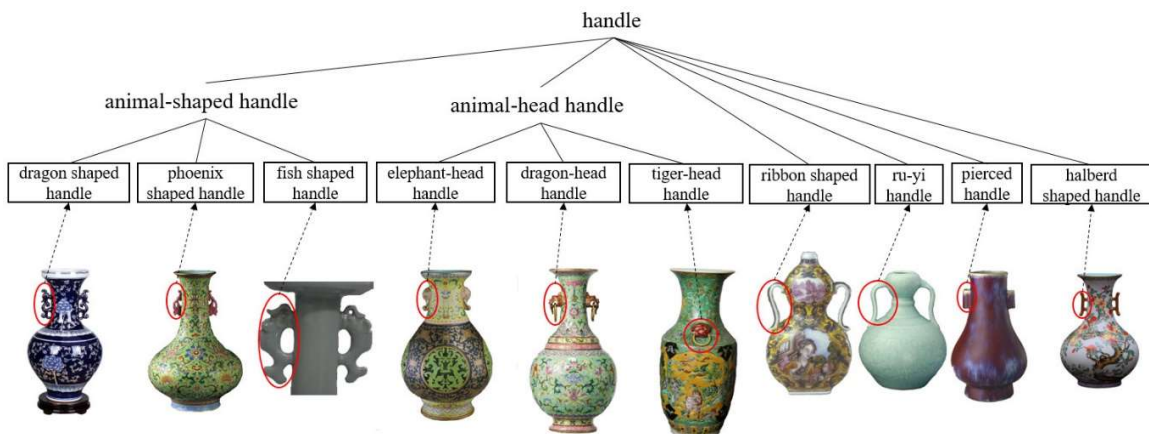


Figure 4. 42. The essential characteristics of the handle.

Ring

The ring is a circle put on the handle. The essential characteristics of the ring component are /with ring/ and /without ring/ (Figure 4.43). The ring depends on the handle. So the relation is the dependence between ring and handle.

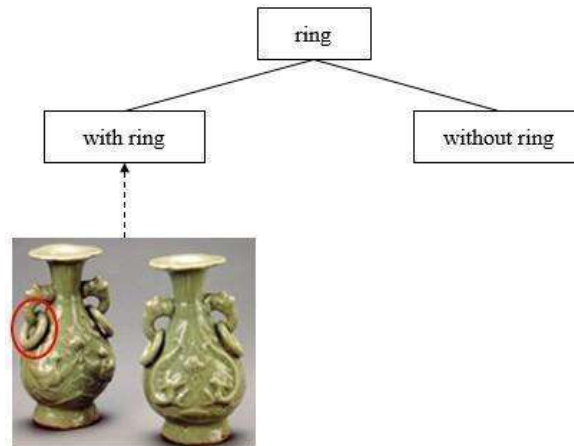


Figure 4. 43. The essential characteristics of the ring component.

Belly

The belly is the rounded or curved part of vases and is between the shoulder and bottom. The belly component has two axes of analysis: the regular shape of a belly, the irregular shape of a belly. The analysis axis of regular shape of belly includes six essential characteristics: /globular belly/, /oblate belly/, /spheroid belly/, /cylindrical belly/, /square belly/, and /round belly/ (Figure 4.44). The /globular belly/ refers to the belly is the globular shape. The /oblate belly/ means the belly is the oblate shape. The /spheroid belly/ is the shape of the belly like a spheroid. The /cylindrical belly/ means the shape of the belly is cylindrical. The /square belly/ refers to the shape of the belly square. The /round belly/ means the shape of the belly is round.

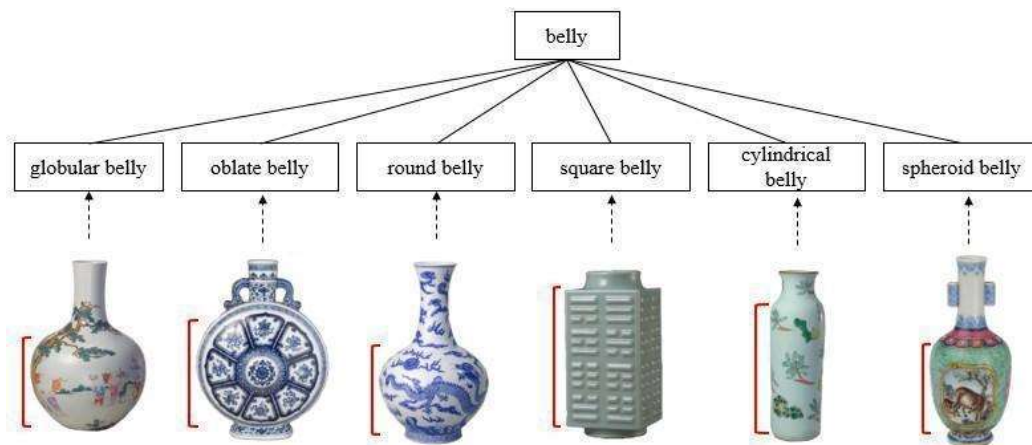


Figure 4. 44. The essential characteristics of the regular shape of the belly.

The axis of analysis of the irregular shape of the belly has seven essential characteristics: /pear-shaped belly/, /flat belly/, /swelling body tapering downwards/, /multi-prism belly/, /drooping belly/, /bulge belly/, and /double gourd-shaped belly/ (Figure 4.45). The /pear-shaped belly/ means the belly looks like a pear. The /flat belly/ refers to the cross-section of the belly is circular, and the front and backspacing is less than the left and right spacing. The /swelling body tapering downwards/ refers to the shape of the belly is swelling body tapering downwards. The /multi-prism belly/ means the belly has multi-prism. The /drooping belly/ means the belly droops, and the maximum belly diameter is lower. The /bulge belly/ means the belly is a bulge. The /double gourd-shaped belly/ means the belly looks like a double gourd shape.

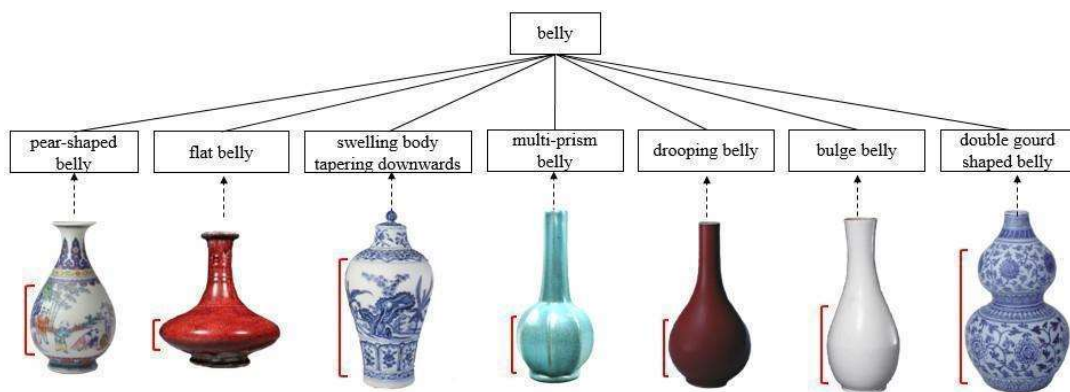


Figure 4. 45. The essential characteristics of the irregular shape of the belly.

Bottom

The bottom is the lowest part of the vases. The bottom component has two essential characteristics: /flat bottom/ and /not flat bottom/ (Figure 4.46). The /flat bottom/ means the bottom is level and smooth and with no curved, high, or hollow parts. The /not flat bottom/ is the opposite of /flat bottom/.

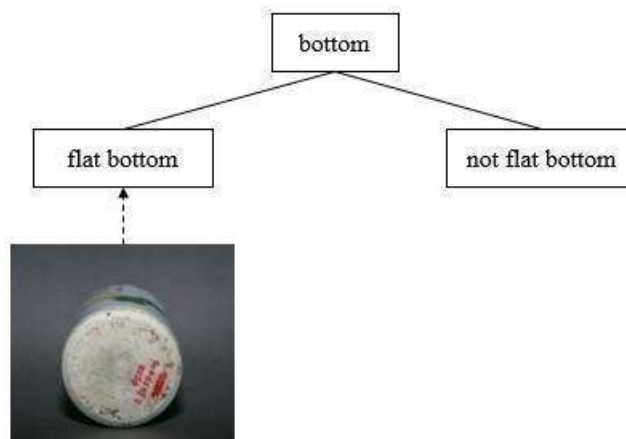


Figure 4. 46. The essential characteristics of the bottom.

Foot

The foot is to support the vase. The foot component has several axes of analysis: foot, foot height, foot shape, foot wall. The foot height, foot shape, and foot wall depend on the vase with a foot. The axis of

analysis of foot has two essential characteristics: /with foot/ and /without foot/ (Figure 4.47). The /with foot/ is the vase is with a foot. The /without foot/ is the vase does not have a foot. The analysis axis of foot height includes two essential characteristics: /high foot/ and /low foot/ (Figure 4.48). The analysis axis of foot shape includes three essential characteristics: /ring foot/, /square foot/, and /concave foot/ (Figure 4.49). The /ring foot/ means that the bottom of vases bears a circle to support vases. The /square foot/ means that the bottom of the vases is square. The /concave foot/ means the bottom looks like a flat bottom, but actually, it is a concave bottom. The analysis axis of the wall of the foot includes three essential characteristics: /outward foot/, /convergence foot/, and /straight foot/ (Figure 4.50). The /outward foot/ refers to the foot is outward. The /convergence foot/ means the foot is convergence. The /straight foot/ means the wall of the foot is straight.

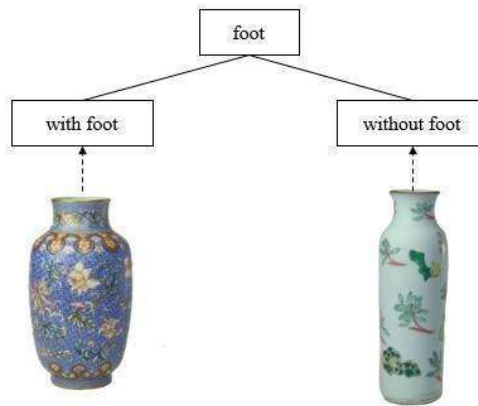


Figure 4. 47. The essential characteristics of foot.

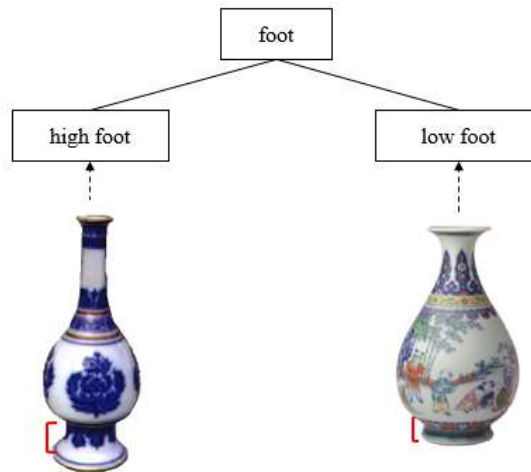


Figure 4. 48. The essential characteristic of foot height.

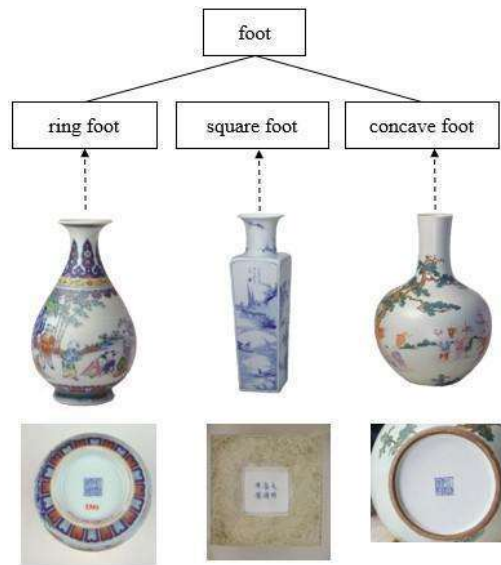


Figure 4. 49. The essential characteristics of foot shape.

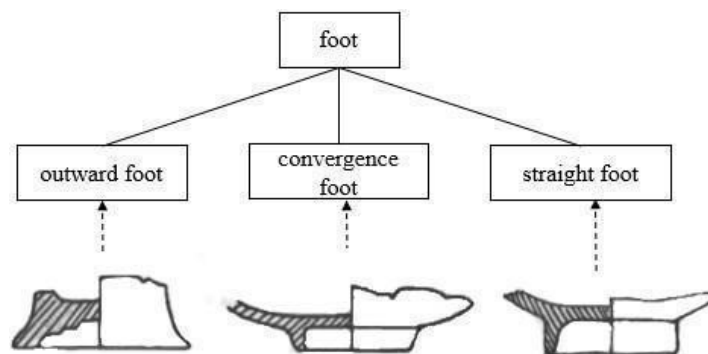


Figure 4. 50. The essential characteristics of the foot wall.

2.5.3 Descriptive characteristic

Descriptive characteristics are also kinds of characteristics. Descriptive characteristics are different from essential characteristics, which decide the concept of objects. Descriptive characteristics are only a kind of description supplement of the object and do not influence the concept. This section will introduce the descriptive characteristics of vases. This domain knowledge of descriptive characteristics has been presented in part Chinese ceramic vessels.

Glaze and Color

The glaze and color are vital characteristics of vases. There are many different types of glaze and color, which reflect the technique level of ceramics. For example, the term “明永乐青花竹石芭蕉纹梅瓶” includes the glaze and color is “青花” (blue-and-white).

Period

The different period has a different feature of vases. In the domain of Chinese ceramic vases, using dynasty and emperor represent the period. So the dynasty and the emperor are two descriptive characteristics. For example, in the name “明永乐青花竹石芭蕉纹梅瓶,” “明永乐” represents the period, which is “明” means the Ming dynasty and “永乐” means the Yongle emperor.

Decoration

The decoration is a generic name of decorative patterns on the surface of ceramics. It has different kinds of decorative patterns. For example, in the name “明永乐青花竹石芭蕉纹梅瓶,” the “竹石芭蕉纹” represents the decoration, which is bamboo and stone and banana-leaf patterns.

Kiln

The kiln is the name of the place where ceramics are produced. Each kiln has a specialized technique of ceramics. Therefore, the kiln is also a vital descriptive characteristic, such as “德化窑”. A TAO CI ontology defines the data property *isProducedIn* refers to a descriptive characteristic kiln.

Diameter

The diameter includes two parts: mouth and foot. The diameter of the mouth and the diameter of the foot are two descriptive characteristics. The height of vases also is an important characteristic, which is regarded as descriptive characteristics.

Museum

The museum refers to which museum the vase is collected. It is not a descriptive characteristic of objects. It has contributed to finding the vase from the different museums, such as The Palace Museum, The National Museum of China, and The Shanghai museum. The TAO CI ontology defines the data property *isCollectedIn* to refer to the museum characteristic.

Image

The image refers to the URL of vases published by the museum. It is not a descriptive characteristic of objects. It could get the image through the URL. TAO CI ontology reuses the *foaf: depiction* to refer to the image.

2.6 Concepts building guided by terms

In our work, the concepts are a stable set of essential characteristics. Our focus is on the vase, whose concept is composed of *{/clay vessel/, /high temperature/, /for decoration/}*. Its definition written in natural language is “Clay vessel for decoration, fired at high temperature”. In practice, we found some special types of terms denoted different types of objects that are different from shapes, such as a garlic-head vase, arrow vase, and plum vase. To reduce the ambiguity of terms in the ontology, we proposed new terms to designate objects. Therefore, this section will focus on presenting these new terms and concepts denoted by these new terms.

2.6.1 Proposing new terms

We were faced with two problems in naming vases in Chinese and in English.

The first one is when there are no proven equivalents in English for Chinese terms, such as “花口瓶”. The Chinese term “蒜头瓶” (“garlic-head vase” in English) illustrates the principle we followed for proposing new equivalent terms. The “蒜头瓶” vases are so named because of the shape of their head: the Chinese character “蒜” is translated as “garlic”, “头” as “head”, and “瓶” as “vase”. The equivalent in English is “garlic-head vase”. Following this principle, the equivalent in English of “花口瓶” is “flower-mouth vase”, because the characters “花”, “口”, and “瓶” are translated as “flower”, “mouth”, and “vase”, respectively.

The second issue is about naming new concepts introduced to distinguished different types of vases. For example, the term “蒜头瓶” (“garlic-head vase” in English) is too general. It denotes two kinds of vases, the first ones with a short neck, the second ones with a long neck. We used the “general term + order” rule for naming such concepts. For example, “garlic-head vase I”, “garlic-head vase II”.

Table 7, 8 shows some new terms.

Table 7. New equivalent English terms

Chinese term	New English term
花口瓶	flower-mouth vase
荸荠瓶	water-chestnut vase
活环瓶	loosing ring vase
贯耳瓶	arrow vase

Table 8. New terms corresponding to new concepts.

Ambiguous term		New term	
Chinese	English	English	Chinese
贯耳瓶	arrow vase	arrow vase I	贯耳瓶 I
		arrow vase II	贯耳瓶 II
		arrow vase III	贯耳瓶 III
蒜头瓶	garlic-head vase	garlic-head vase I	蒜头瓶 I
		garlic-head vase II	蒜头瓶 II
葫芦瓶	double-gourd vase	double-gourd vase I	葫芦瓶 I
		double-gourd vase II	葫芦瓶 II
		double-gourd vase III	葫芦瓶 III

胆式瓶	gall-bladder vase	gall-bladder vase I	胆式瓶 I
		gall-bladder vase II	胆式瓶 II
橄榄瓶	olive-shaped vase	olive-shaped vase I	橄榄瓶 I
		olive-shaped vase II	橄榄瓶 II
梅瓶	plum vase	plum vase I	梅瓶 I
		plum vase II	梅瓶 II
花口瓶	flower-mouth vase	flower-mouth vase I	花口瓶 I
		flower-mouth vase II	花口瓶 II
天球瓶	vault-of-heaven vase	vault-of-heaven vase I	天球瓶 I
		vault-of-heaven vase II	天球瓶 II

2.6.2 Building concepts guided by terms

The following will present these new terms and concepts denoted by these new terms.

Arrow Vase

The term “arrow vase” designates the concept <OneMouthVase without lid long neck without ring pierced handle flat bottom>. The formal definition of the concept is:

<OneMouthVase without lid long neck without ring pierced handle> ::= <OneMouthVase> + /without lid/ + /long neck/ + /without ring/ + /pierced handle/.

However, the term “arrow vase” denotes the different types of vases. We proposed three new terms based on the term “arrow vase”: “arrow vase I”, “arrow vase II”, and “arrow vase III”. Figure 4.51 shows the hierarchy of the arrow vase.



Figure 4. 51. The hierarchy of the arrow vase.

The term “arrow vase I” denotes the concept <ArrowVase square mouth slanting shoulder bulge belly square foot>. The formal definition of the concept is:

<ArrowVase square mouth slanting shoulder bulge belly square foot> ::= <ArrowVase> + /square mouth/ + /slanting shoulder/ + /bulge belly/ + /square foot/.

The term “arrow vase II” denoted the concept <ArrowVase straight mouth slanting shoulder bulge belly ring foot>. The formal definition of the concept is:

<ArrowVase straight mouth slanting shoulder bulge belly ring foot> ::= <ArrowVase> + /straight mouth/ + /slanting shoulder/ + /bulge belly/ + /ring foot/.

The term “arrow vase III” denoted the concept <ArrowVase straight mouth folding shoulder swelling body tapering downward ring foot>. The formal definition of the concept is:

<ArrowVase straight mouth folding shoulder swelling body tapering downward ring foot> ::= <Arrow vase> + /straight mouth/ + /folding shoulder/ + /swelling body tapering downwards/ + /ring foot/.

Double-gourd vase

The term “double-gourd vase” denotes the concept <OneMouthVase small mouth short neck without ring with slanting shoulder gourd shaped belly>. The formal definition of the concept is:

<OneMouthVase small mouth short neck without ring with slanting shoulder gourd shaped belly flat bottom> ::= <OneMouthVase> + /small mouth/ + /short neck/ + /without ring/ + /slanting shoulder/ + /gourd shaped belly/.

Based on this term, we proposed three new terms to designate the objects: “double-gourd vase I”, “double-gourd vase II”, and “double-gourd vase III”. Figure 4.52 displays the hierarchy of the double-gourd vase.

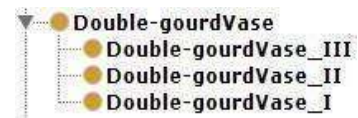


Figure 4. 52. The hierarchy of the double-gourd vase.

The term “double-gourd vase I” denotes the concept <Double-gourdVase without lid without handle ring foot >. The formal definition of the concept is based on essential characteristics:

<Double-gourdVase without lid without handle ring foot> ::= <Double-gourdVase> + /without lid/ + /without handle/ + /ring foot/.

The term “double-gourd vase II” denotes the concept <Double-gourdVase without lid ribbon shaped handles square foot>. The formal definition of the concept is based on essential characteristics:

<Double-gourdVase without lid ribbon shaped handles square foot> ::= <Double-gourdVase> + /without lid/ + /ribbon shaped handle/ + /square foot/.

The term “double-gourd vase III” denotes the concept <Double-gourdVase with lid without handle ring foot>. The formal definition of the concept is based on essential characteristics:

<Double-gourdVase with lid without handle ring foot> ::= <Double-gourdVase> + /with lid/ + /without handle/ + /ring foot/.

Loosing ring vase

The term “loosing ring vase” denotes the concept <OneMouthVase without lid plate shaped mouth long neck fish shaped handle with ring slanting shoulder drooping belly high foot outward foot ring foot>, whose formal definition is based on the essential characteristics:

<OneMouthVase without lid plate shaped mouth long neck fish shaped handle with ring slanting shoulder drooping belly high foot outward foot ring foot> ::= < OneMouthVase> + / without lid / + /plate shaped mouth/ + /long neck/ + /slanting shoulder/ + /drooping belly/ + /fish shaped handle/ + /ring/ + /high foot/ + /ring foot/ + /outward foot/.

Gall-bladder Vase (alternative term: gall-shaped vase)

The term “gall-bladder vase” denotes the concept <OneMouthVase without lid long neck slender neck slanting shoulder without handle without ring drooping belly ring foot>, whose definition of formal is as follows:

<OneMouthVase without lid long neck slender neck slanting shoulder without handle without ring drooping belly ring foot> ::= < OneMouthVase> + / without lid / + /slender neck/ + /long neck/ + /slanting shoulder/ + /without handle/ + /without ring/ + /drooping belly/ + /ring foot/.

We proposed two new terms to designate the objects: “gall-bladder vase I” and “gall-bladder vase II”. Figure 4.53 shows the hierarchy of the gall-bladder vase.

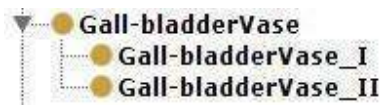


Figure 4. 53. The hierarchy of the gall-bladder vase.

The term “gall-bladder vase I” denotes the concept <Gall-bladder vase small mouth>, which is based on the essential characteristics. The formal definition of the concept is:

<Gall-bladder vase small mouth> ::= <Gall-bladderVase> + /small mouth/.

The term “gall-bladder vase II” denotes the concept <Gall-bladder vase straight mouth>. The formal definition of the concept is: <Gall-bladder vase straight mouth> ::= <Gall-bladderVase> + /straight mouth/.

Garlic-head vase (alternative term: garlic-mouth vase)

The term “garlic-head vase” denotes the concept <OneMouthVase garlic shaped mouth without lid without ring flat bottom ring foot>, which is based on the essential characteristics. Its formal definition is:

<OneMouthVase garlic shaped mouth without lid without ring ring foot> ::= <OneMouthVase> + /garlic shaped mouth/ + / without lid/ + / without ring / + /ring foot/.

We proposed two terms to designate the objects: “garlic-head vase I” and “garlic-head vase II”. Figure 4.54 shows the hierarchy of the garlic-head vase.

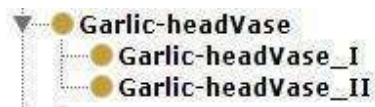


Figure 4. 54. The hierarchy of the garlic-head vase.

The term “garlic-head vase I” denotes the concept <Garlic-headVase short neck circle shoulder ru-yi shaped handle globular belly>, which is based on the essential characteristics. Its formal definition is:

<Garlic-headVase short neck circle shoulder ru-yi shaped handle globular belly> ::= <Garlic-headVase > + /short neck/ + /circle shoulder/ + /ru-yi shaped handle/ + /globular belly/.

The term “garlic-head vase II” denotes the concept <Garlic-headVase slender neck long neck slanting shoulder without handle bulge belly>, which is based on the essential characteristics. Its formal definition is:

<Garlic-headVase slender neck long neck slanting shoulder without handle bulge belly> ::= <Garlic-headVase > + /slender neck/ + /long neck/ + /slanting shoulder/ + /without handle/ + /bulge belly/.

Olive-shaped vase

The term “olive-shaped vase” denotes the concept <OneMouthVase without lid slanting shoulder without handle without ring bulge belly ring foot>, which is based on the essential characteristics. The formal definition of the concept is:

<OneMouthVase without lid slanting shoulder without handle without ring bulge belly ring foot> ::= <OneMouthVase > + /without lid/ + / slanting shoulder / + /without ring/ + /bulge belly/ + /ring foot/.

We proposed two terms to designate the objects: “olive-shaped vase I” and “olive-shaped vase II”. Figure 4.55 displays the hierarchy of the olive-shaped vase.

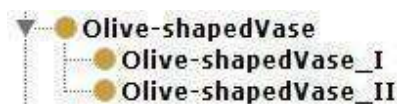


Figure 4. 55. The hierarchy of the olive-shaped vase.

The term “olive-shaped vase I” denotes the concept <Olive-shapedVase outward mouth slender neck long neck outward foot>, whose formal definition is:

<Olive-shapedVase outward mouth slender neck long neck outward foot> ::= <Olive-shapedVase> + /outward mouth/ + /slender neck/ + /long neck/ + /outward foot/.

The term “olive-shaped vase II” denotes the concept <Olive-shapedVase straight mouth short neck>, which is based on the essential characteristics. The formal definition of the concept is:

<Olive-shapedVase straight mouth short neck> ::= <Olive-shapedVase> + /straight mouth/ + /short neck/.

Plum vase

The term “plum vase” denotes the concept <OneMouthVase small mouth short neck circle shoulder without handle without ring swelling body tapering downward ring foot>, whose formal definition is:

<OneMouthVase small mouth short neck circle shoulder without handle without ring swelling body tapering downward flat bottom ring foot> ::= <OneMouthVase> + /small mouth/ + /short neck/ + /circle shoulder/ + /swelling body tapering downwards/ + /without handle/ + /without ring/ + /ring foot/.

We proposed two new terms to designate the objects: “plum vase I” and “plum vase II”. Figure 4.56 displays the hierarchy of the plum vase.



Figure 4. 56. The hierarchy of the plum vase.

The term “plum vase I” denotes the concept <PlumVase with lid>, whose formal definition is based on the essential characteristics: <PlumVase with lid> ::= <plum vase> + /with lid/.

The term “plum vase II” denotes the concept <PlumVase lip mouth without lid>, which is based on the essential characteristics. The formal definition of the concept is: <Plum vase lip mouth without lid> ::= <PlumVase> + /lip mouth/ + /without lid/.

Flower-mouth vase

The term “flower-mouth vase” denotes the concept <OneMouthVase without lid flower shape mouth slender neck without handle without ring slanting shoulder ring foot>, which is based on the essential characteristics. The formal definition of the concept is:

<OneMouthVase without lid flower shape mouth slender neck without handle without ring slanting shoulder flat bottom ring foot> ::= <OneMouthVase> + /without lid/ + /flower shape mouth/ + /slender neck/ + /ring foot/ + /without handle/ + /without ring/ + /slanting shoulder/.

We proposed two new terms to designate the objects: “flower-mouth vase I” and “flower-mouth vase II”. Figure 4.57 displays the hierarchy of the flower-mouth vase.

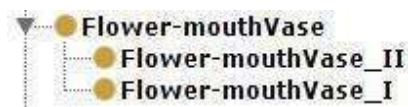


Figure 4. 57. The hierarchy of the flower-mouth vase.

The term “flower-mouth vase I” denotes the concept <Flower-mouthVase long neck globular belly>, which is based on the essential characteristics. The formal definition of the concept is:

< Flower-mouthVase long neck globular belly> ::= <Flower-mouthVase> + /long neck/ + /globular belly/.

The term “flower-mouth vase II” denotes the concept <Flower-mouthVase short neck round belly outward foot>, which is based on the essential characteristics. The formal definition of the concept is:

<Flower-mouthVase short neck round belly outward foot> ::= <Flower-mouthVase> + /short neck/ + /round belly/ + /outward foot/.

Vault-of-heaven vase (alternative term: globular vase)

The term “vault-of-heaven vase” denotes the concept <OneMouthVase without lid straight neck circle shoulder without handle without ring globular belly flat bottom>, which is based on the essential characteristics. The formal definition of the concept is:

<OneMouthVase without lid straight neck circle shoulder without handle without ring globular belly flat bottom> ::= /OneMouthVase/ + /without lid/ + /straight neck/ + /circle shoulder/ + /without handle/ + /without ring/ + /globular belly/ + /flat bottom/.

We proposed two new terms to designate the objects: “vault-of-heaven vase I” and “vault-of-heaven vase II”. Figure 4.58 displays the hierarchy of the vault-of-heaven vase.

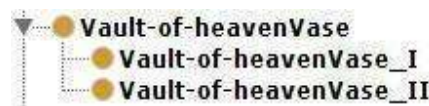


Figure 4. 58. The hierarchy of the vault-of-heaven vase.

The term “vault-of-heaven vase I” denotes the concept <Vault-of-heavenVase small mouth lip mouth without foot>, which is based on the essential characteristics. The formal definition of the concept is

<Vault-of-heavenVase small mouth lip mouth without foot> ::= /Vault-of-heavenVase/ + /small mouth/ + /lip mouth/ + /without foot/.

The term “vault-of-heaven vase II” denotes the concept <Vault-of-heavenVase straight mouth concave foot>, which is based on the essential characteristics. The formal definition of the concept is: <Vault-of-heavenVase straight mouth concave foot> ::= /Vault-of-heavenVase / + /straight mouth/ + /concave foot/.

Water-chestnut vase

The term “water-chestnut vase” denotes the concept <OneMouthVase without lid lip mouth long neck slender neck slanting shoulder without handle without lid oblate belly flat bottom ring foot>, which is based on the essential characteristics. The formal definition of the concept is:

<OneMouthVase without lid lip mouth long neck slender neck slanting shoulder without handle without lid oblate belly ring foot > ::= / OneMouthVase / + /without lid/ + /lip mouth/ + /long neck/ + /slender neck/ + /slanting shoulder/ + /without handle/ + /without lid/ + /oblate belly/ + /ring foot/.

2.7 Building ontology in Protégé

There are two tools to develop ontology: Tedi and Protégé. Tedi is a unique assistant tool for ontoterminology, which has been presented in the previous chapter. However, this section will focus on Protégé and how to implement the term-and-characteristic guided method. Recall the implementation of the term-and-characteristics guidance approach that is presented in chapter 1.5 of part IV. The work of terminology includes two dimensions: the linguistic dimension and conceptual dimension that includes essential characteristics, descriptive characteristics, concepts, objects, and relations. Figure 4.59 shows Protégé expression logic through the object properties to express the relation between classes.

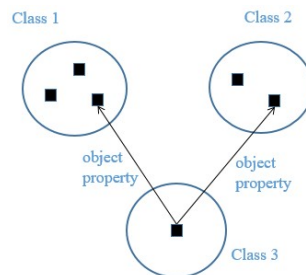


Figure 4. 59. The logic of Protégé.

2.7.1 Conceptual dimension

The conceptual dimension includes four main principles: essential characteristic, concept, descriptive characteristic, and relation. The following will present how to express these four principles in Protégé.

2.7.1.1 Essential characteristic

Recall the Implementation chapter that essential characteristics are expressed as classes. Therefore, essential characteristics corresponding to parts of a vase are subclasses of the Component class: Lid class, Mouth class, Neck class, Handle class, Shoulder class, Belly class, Foot class. Some being themselves specialized in subclasses according to the different types of parts: LongNeck and ShortNeck subclasses of the Neck class, RingFoot, and SquareFoot subclasses of the Foot class. Essential characteristics corresponding to functions, such as /for decoration/ are subclasses of Function class. Owning an essential characteristic for a concept (class) is translated into a restriction of an object property whose range is the class associated with the essential characteristic. It means that the concept (class) is a subclass of the anonymous class defined by the restriction. For example, owning the essential characteristic /long neck/ will be translated into the following restriction of the ‘hasComponent’ object property: ‘hasComponent’ some LongNeck. The following restriction of the ‘hasFunction’ object property: ‘hasFunction’ some FunctionForDecoration expresses the owning of the essential characteristic /for decoration/.

Protégé relies on the open-world assumption. It means that what is not known to be true is unknown. It is necessary to express information corresponding to essential characteristics, such as /without handle/, /without lid/, /without foot/. The object property restriction allows us to do that. For example, owning the

/without handle/ essential characteristic will be translated into the following object property restriction not ('hasComponent' some Handle).

2.7.1.2 Concept

Recall the Implementation chapter that concept is translated as a class in Protégé. The concept name could not be used as the class name because it can be too long. So the term denoting concepts is used as the class name. For example, the term “Lantern Shaped Vase” denotes the concept < Vase one and outward mouth short neck slanting shoulder cylindrical belly with ring foot >, which is expressed as a class, whose name is Lantern Shaped Vase. To express the concept for a class, we define a data property *conceptName* used to annotate the concept of a class.

2.7.1.3 Descriptive characteristic

There are many descriptive characteristics: *dynasty*, *emperor*, *kiln*, *glaze-color*, *height*, the *diameter of mouth*, *diameter of foot*, *decoration*, *museum*, and *image*. The Descriptive characteristics are represented either as data properties if their value is a data literal, or as object properties and classes if the value is an individual. For example, the descriptive characteristic *height* is expressed as data property *height*, which domain is the Vase class, and range is the string literary. The decoration is represented by the data property *isDecoratedBy*, which domain is Vessel class, and the range is a string. The data property *isCollectedIn* represents the descriptive characteristic - *museum*, which domain is Vessel class, and the range is a string. The data property *isProducedIn* represents the descriptive characteristic *kiln*, which domain is Vessel class, and the range is a string. The *dynasty*, *emperor*, *glaze-color* are translated as a class in Protégé because their values are individuals.

2.7.1.4 Individual

The individual is the extent of a class. The research objects will be expressed as an individual of corresponding the class. Due to the name of Chinese ceramic vases is very complicated, in Protégé, we use the regular “shape term of vase + order” to express the name of individuals. For example, the “arrow vase 004” is an object of the concept denoted by the term “arrow vase II”. The name of the individual “arrow vase 004” is “flame glaze arrow vase, Qianlong mark of Qing dynasty”, which is too long. So we use the name “arrow vase 004” to replace it in our ontology.

2.7.1.5 Relation

Relations between concepts are translated as object properties, such as, *hasFunction*, *hasComponent*, *isMadeOf*. Let us note that in this work, not all the different kinds of part-of relationships will be taken into account (Winston et al., 1987). We will distinguish in a taxonomy of part-whole relations only the ‘Component/Integral Object’ relationship expressed as the restriction on the object property ‘has’, and the ‘Stuff/Object’ relationship expressed as a restriction on the object property ‘*isMadeOf*’. For example, the object property *hasComponent*, whose domain is Vessel class, and range is Component class (Vessel *hasComponent* Component). The object property *isMadeOf*, whose domain is Vessel class, and range is Material Class (Vessel *isMadeOf* Material).

2.7.2 Linguistic dimension

2.7.2.1 Term

The term is the start point in our work. The term designates the concept corresponding to the object. So, in Protégé, the term will be expressed in a label. There are two preparings to use for expressing terms: `skos:prefLabel` and `skos:altLabel`. The `skos:prefLabel` is used to annotate the preferred term. The `skos:altLabel` is used to annotate alternative terms.

2.7.2.2 Term Definition

In Conceptual Terminology, in the sense of the ISO for which a term is a verbal designation of a concept, term definitions are *definitions of things*. It means that the definition of a term is a “translation” (explanation) in the natural language of the formal definition of the concept denoted by the term.

Definition in natural language, in general, follows the Aristotelian pattern of definition in genus and differentia(e). It starts with a hypernym denoting a generic concept followed by the linguistic expressions corresponding to the specific and essential characteristic(s) of the concept.

For example (see Figure 4.60), the term “arrow vase” (“贯耳瓶”) is represented in Protégé as a `skos:prefLabel`. It denotes the concept `<OneMouthVase without lid long neck without ring pierced handle >` represented by the class `ArrowVase` in Protégé. The formal definition of the concept based on essential characteristics is:

`<OneMouthVase without lid long neck without ring pierced handle>::= <OneMouthVase> + /without lid/ + /long neck/ + /without ring/ + /pierced handle/.`

This formal definition is translated into Protégé as the intersection of 5 classes, a named class corresponding to the genus (`OneMouthVase`) and four anonymous classes (property restrictions) corresponding to the four essential characteristics (`/without lid/`, `/long neck/`, `/without ring/`, and `/pierced handles/`).

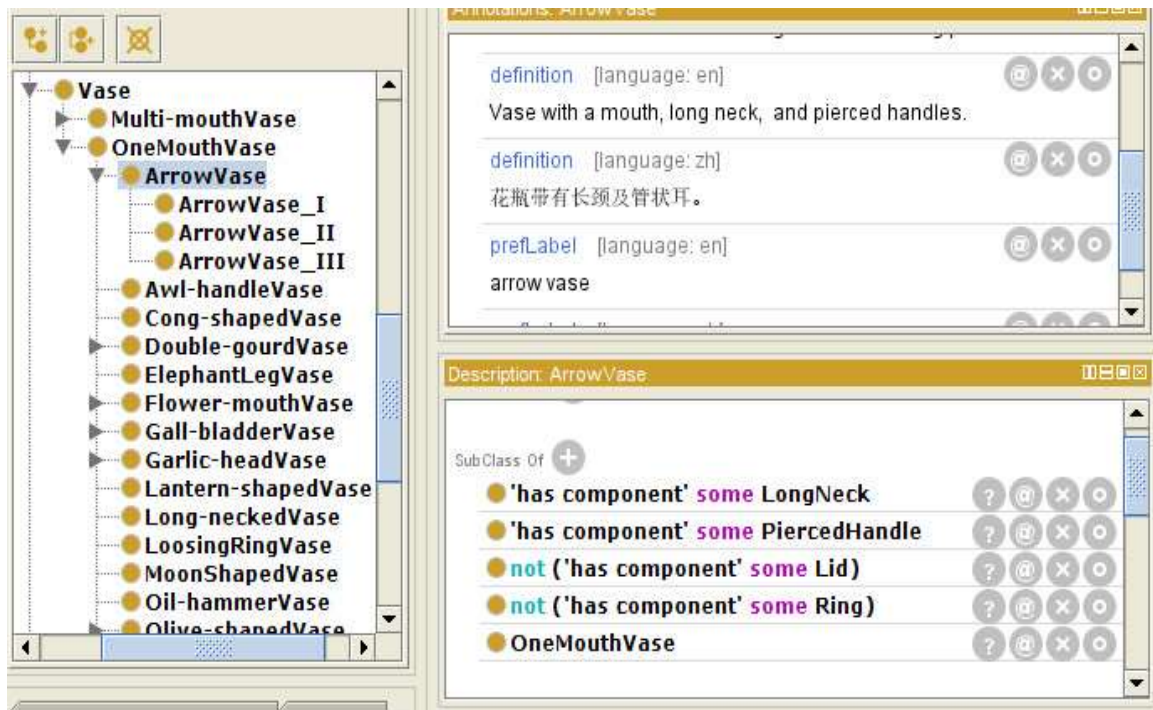


Figure 4. 60. Definition of the ArrowVase class in Protégé.

The definition of terms in natural language cannot be directly and easily generated from the logical definition of concepts in Protégé. Nevertheless, we can give some guidelines for writing them based on the principles we have proposed for translating essential characteristics in Protégé. Let us recall that the essential characteristics are represented as named classes. Owning an essential characteristic for a concept (class) is expressed as a restriction of an object property whose range is the class associated with the essential characteristic. Hence the following principle for writing term definition:

The definition of a term, represented by the `skos:definition` property, starts with:

- a hypernym corresponding to the label (`skos:prefLabel`) of the named superclass (or one of them if there are more than one named superclass). In our example: the “vase” label of the Vase class;

followed by:

- the linguistic units expressing the specific and essential characteristics are built from the label(s) (`skos:prefLabel`) of the named classes implementing the essential characteristic(s) involved in the property restriction(s). In our example: “long neck” and “pierced handle”.

The definition of the term “arrow vase” is then “Vase with long neck and pierced handles.”

Let us note that the direct superclass can have no designation in a given natural language. Concepts (classes) without designation in any given language allow to structure the conceptual system. Let us recall that the network of terms does not necessary match with the network of concepts (Roche 2015). In this case, we have to find the first superclass with a label (in the selected natural language) and add the specific characteristics of the direct superclass.

Let us go back to the previous example. In fact, the first division of vases is done into two classes according to the number of mouths: one mouth or multi-mouths (see Figure 4.32):

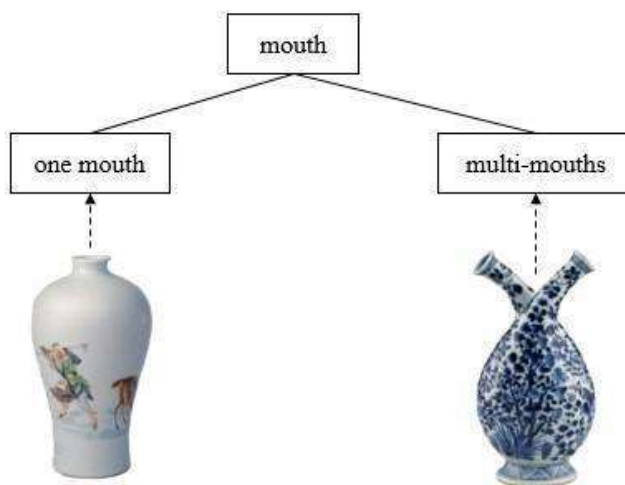


Figure 4.32. The essential characteristic of mouth quantity.

The ArrowVase class is a subclass of the OneMouthVase class, which is itself a subclass of the named class Vase and a subclass of the anonymous class OneMouthVase (property restriction) corresponding to the essential characteristic /one mouth/.

The OneMouthVase has no designation neither in English nor in Chinese. The first superclass with a designation is the Vase class. Knowing that the specific characteristic of OneMouthVase is /one mouth/, the complete definition of “arrow vase” is then “Vase with a mouth, long neck and pierced handles.”

Since the /long neck/ characteristic is applicable only for one-mouth vases, the definition of “arrow vase” can be simplified, following the principle of economy of language (a kind of ellipsis in this case), into “Vase with long neck and pierced handles”.

The Chinese-English Glossary of Cultural Relics and Archeology (王殿明 & 杨绮华, 2005) define “arrow vase” (“贯耳瓶”) as “vase with pierced handles” (Figure 4.61).

贯耳瓶 vase with pierced handles

Figure 4. 61. Definition of an “arrow vase” in the Chinese-English Glossary of Cultural Relics and Archeology.

The principle of economy of language is systematically used in writing definition in natural language. In particular, writing definitions in natural language will rely on a “closed-world” assumption. If the /without lid/ essential characteristic is as important as /with lid/ characteristic from a formal point of view, the definition in natural language of “arrow vase” will not be precise that this kind of vase is without lid.

Following the same approach, the definition of the term “double-gourd vase” is “Vase with a small mouth and a gourd-shaped belly” when the Chinese-English Glossary of Cultural Relics and Archeology (王殿明 & 杨绮华, 2005) define it as “vase in the shape of a gourd” (Figure 4.62).

葫芦瓶 double-gourd vase; vase in the shape of a gourd

Figure 4. 62. Definition of an “double-gourd vase” in Chine-English Glossary of Cultural Relics and Archeology.

2.7.2.3 Ontolex-Lemon

Reducing a term to a label on a concept is not satisfactory, even if we can put additional linguistic information using annotations such as `rdfs:comment`, `skos:note`, `skos:example`, etc.

Even if it is not the main purpose of our work, let us quote two approaches, which could be the subject of future works, to explicitly represent the linguistic dimension of a terminology.

The first one aims to stay in the same environment (Protégé). Terms can be explicitly represented as individuals of a dedicated class (let us name it Term), and linguistic relationships as object properties and data properties. For example, terms could be linked through the object property “designates” with the Term class as domain and the Vessel class as a range.

The second approach consists of adding an explicit level for the linguistic dimension. The Ontolex-lemon^{115,116} provides a core vocabulary to represent linguistic information related to an ontology. It is targeted at the representation of dictionaries and any other linguistic resource containing lexicographic data and addresses structures and annotations commonly found in lexicography (Figure 4.63).

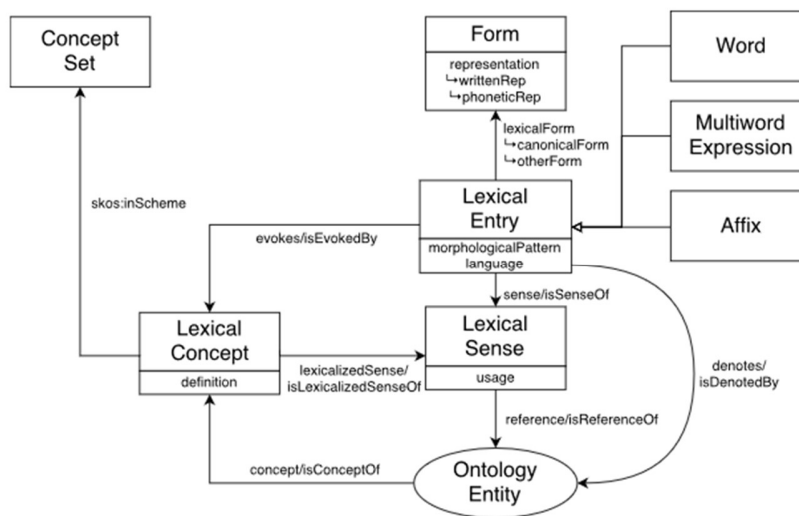


Figure 4. 63. Lemon-Ontolex core.

¹¹⁵ <https://www.w3.org/2016/05/ontolex/>

¹¹⁶ “The OntoLex-Lemon Model: development and applications” John P. McCrae¹, Julia Bosque-Gil², Jorge Gracia², Paul Buitelaar¹, Philipp Cimiano. <http://john.mccr.ae/papers/mccrae2017ontolex.pdf>

2.8 Integration

Ontology mapping and linking are essential methods to broaden the ontology content. To enrich the ontology content, The TAO CI ontology will link with other resources.

2.8.1 Resources

Resources should be standard and published on the web. For the TAO CI ontology, there are two kinds of resources: CIDOC CRM and AAT.

The CIDOC CRM is an ISO standard used for information integration in cultural heritage. The CIDOC CRM achieves this by providing definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation and of general interest for the querying and exploration of such data. In the CIDOC CRM model, we select the vocabularies mapped: E4 Period, E21 Person, E57 Material, E22 Human-Made Object.

E4 Period: This class comprises sets of coherent phenomena or cultural manifestations occurring in time and space. E4 Period class is used to describe prehistoric or historic periods such as the “Neolithic Period”, the “Ming Dynasty” or the “McCarthy Era”, but also geopolitical units and activities of settlements are regarded as special cases of E4 Period¹¹⁷.

E21 Person: This class comprises real persons who live or are assumed to have lived¹¹⁸.

E57 Material: This class is a specialization of E55 Type and comprises the concepts of materials¹¹⁹.

E22 Human-Made Object: This class comprises physical objects purposely created by human activity¹²⁰.

The AAT is a structured vocabulary containing terms and other information about concepts. Terms in AAT may be used to describe art, architecture, decorative arts, material culture, and archival materials. It is constructed to allow their use in linked data. Releasing the Getty vocabularies as Linked Open Data is part of the Getty's ongoing effort to make our knowledge resources freely available to all. In the TAO CI ontology, there are many vocabularies linked to the AAT resource, such as temperature, function, glaze-colors.

2.8.2 Reusing vocabularies & ontologies

Reusing vocabularies and ontologies are a primary method to develop ontologies. In TAO CI ontology, we also reused vocabularies and ontologies, which included SKOS, Dublin Core Metadata Initiative, and FOAF.

¹¹⁷ <http://www.cidoc-crm.org/Entity/e4-period/version-6.2>

¹¹⁸ <http://www.cidoc-crm.org/Entity/e21-person/version-6.2>

¹¹⁹ <http://www.cidoc-crm.org/Entity/e57-material/version-6.2>

¹²⁰ <http://www.cidoc-crm.org/Entity/e22-man-made-object/version-6.1>

In the SKOS model, there are five vocabularies reused in TAO CI ontology: skos: definition, skos: prefLabel, skos: altLabel, skos: broadMatch, and skos: exactMatch.

The skos: definition has been used to provide a plain text definition for a resource of type class. It is an instances of owl:AnnotationProperty and is sub-properties of skos:note¹²¹.

The skos: prefLabel and skos: altLabel are used to annotate the terms. The skos:prefLabel and skos:altLabel are each instances of owl:AnnotationProperty and are each sub-properties of rdfs:label. The rdfs:range of each of skos:prefLabel and skos:altLabel is the class of RDF plain literals ¹²².

The skos: broadMatch is used to state a hierarchical mapping link between two concepts. The skos: exactMatch is used to link two concepts, indicating a high degree of confidence that the concepts can be used interchangeably across a wide range of information retrieval applications¹²³. The skos:exactMatch is a sub-property of skos:closMatch¹²⁴.

In the DC model, there are three vocabularies to be used in TAO CI ontology: dc: publisher, dc: creator, and dc: license. The dc: publisher means to annotate the publisher of ontology. The dc: creator is used to annotating the ontology creator. The dc: license is used to declare the license of ontology. Their definitions are as follows:

dc: publisher: the definition is “An entity responsible for making the resource available” ¹²⁵.

dc: creator: “An entity responsible for making the resource” ¹²⁶.

dc: license: “A legal document giving official permission to do something with the resource.”¹²⁷

In the FOAF model, The vocabulary foaf:depiction is used in TAO CI ontology. The foaf:depiction is used to annotate the URL of an image.

foaf:depiction : The depiction property is a relationship between a thing and an Image that depicts it¹²⁸.

2.8.3 Selecting vocabularies for mapping and linking

Mapping and linking are different in the domain of ontology. The mapping focuses on the concept scheme, such as ontology mapping, while linking focuses on data, such as linking data. So in ontology, the ontology mapping refers to a map between different ontology concept schemes, while linking data refers to link data (entity) with different resources. Based on the above, the distinction between mapping and linking,

¹²¹ <https://www.w3.org/TR/skos-reference/#mapping>

¹²² <https://www.w3.org/TR/skos-reference/#mapping>

¹²³ <https://www.w3.org/TR/skos-reference/#mapping>

¹²⁴ <https://www.w3.org/TR/skos-reference/#mapping>

¹²⁵ <https://www.dublincore.org/specifications/dublin-core/dcmi-terms/#http://purl.org/dc/terms/publisher>

¹²⁶ <https://www.dublincore.org/specifications/dublin-core/dcmi-terms/#http://purl.org/dc/terms/creator>

¹²⁷ <https://www.dublincore.org/specifications/dublin-core/dcmi-terms/#http://purl.org/dc/terms/license>

¹²⁸ http://xmlns.com/foaf/spec/#term_depiction

vocabularies used to express mapping or linking relations are different. Therefore, there is a distinction between mapping and linking.

For mapping, we often use the mapping properties of SKOS: `skos:closeMatch`, `skos:exactMatch`, `skos:broadMatch`, `skos:narrowMatch`, and `skos:relatedMatch`. The `skos:closeMatch` is used to link two concepts that are sufficiently similar that they can be used interchangeably in some information retrieval applications. The `skos:broadMatch` and `skos:narrowMatch` are used to express a hierarchical mapping between two concepts. The `skos:relatedMatch` is used to express an associative mapping between two concepts. The `skos:exactMatch` is used to link two concepts, indicating a high degree of confidence that the concepts can be used interchangeably across a wide range of information retrieval applications¹²⁹. The SKOS mapping properties are only used to link concepts in different concept schemes.

For linking, we often use the properties of the OWL: `owl:sameAs` and `owl:seeAlso`. The OWL property `owl:sameAs` links an individual to another individual. Such an `owl:sameAs` statement indicates that two URI references refer to the same thing: the individuals have the same "identity"¹³⁰. Therefore, in OWL Full, where a class could be treated as an instance of classes, the `owl:sameAs` constructs to define class equality, thus indicating that two concepts have the same intensional meaning. The RDFS property `rdfs:seeAlso` is used to indicate a resource that might provide additional information about the subject resource.

In the TAO CI ontology, we use the SKOS mapping properties to map linking other concept schemes, such as CIDOC CRM, AAT. For the individual of TAO CI ontology, we use `owl:sameAs` and `rdfs:seeAlso` to link to other data resources, such as the museum.

¹²⁹ <https://www.w3.org/TR/skos-reference/#mapping>

¹³⁰ <https://www.w3.org/TR/owl-ref/#sameAs-def>

Chapter 3. TAO CI Ontology Description

The TAO CI ontology has been published on <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl>.

There are 165 classes, 11 object properties, 8 data properties, 132 individuals, and 3124 axioms (table 9).

Table 9. TAO CI ontology metrics.

<i>Metric</i>	<i>Value</i>
<i>Axiom count</i>	3124
<i>Logical axiom count</i>	1509
<i>Class count</i>	165
<i>Object property count</i>	11
<i>Object property - domain axioms count</i>	11
<i>Object property - range axioms count</i>	11
<i>Data property count</i>	8
<i>Data property - domain axioms count</i>	8
<i>Data property - range axioms count</i>	8
<i>Individual count</i>	132
<i>Annotation assertion axioms count</i>	1288

At the beginning of creating an ontology, the prefix declaration is an important work, which includes the ontology created namespace and reusing or mapping ontology namespace. In TAO CI ontology, the prefix declarations are as table 10. The TAO CI ontology mapped to the third-part ontologies is in table 11.

Table 10. Prefix declarations of TAO CI ontology.

<i>Prefix declarations</i>	<i>Namespace</i>
crm	http://www.cidoc-crm.org/cidoc-crm/
dc	http://purl.org/dc/elements/1.1/
dcterms	http://purl.org/dc/terms/
otc	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#
owl	http://www.w3.org/2002/07/owl#
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#

rdfs	http://www.w3.org/2000/01/rdf-schema#
skos	http://www.w3.org/2004/02/skos/core#
xsd	http://www.w3.org/2001/XMLSchema#
foaf	http://xmlns.com/foaf/0.1/

Table 11. The TAO CI ontology mapping to third-part ontologies.

<i>TAO CI ontology class</i>	<i>skos:broadMatch</i>
otc:Dynasty	crm:E4_Period
otc:Emperor	crm:E21_Person
otc:Vessel	crm:E22_Man-Made_Object
<i>TAO CI ontology class</i>	<i>skos:exactMatch</i>
otc:Material	crm:E57_Material
<i>TAO CI ontology class</i>	<i>rdfs:seeAlso</i>
otc:Basin	http://vocab.getty.edu/page/aat/300045614
otc:Belly	http://vocab.getty.edu/page/aat/300203467
otc:Bottom	http://vocab.getty.edu/page/aat/300121967
otc:Bowl	http://vocab.getty.edu/page/aat/300203596
otc:Box	http://vocab.getty.edu/page/aat/300045643
otc:Bronze	http://vocab.getty.edu/page/aat/300010957
otc:Clay	http://vocab.getty.edu/page/aat/300010439
-----	-----

3.1 Class

The TAO CI ontology includes 165 classes. The core class has Component class, Dynasty class, Emperor class, Function class, GlazeAndColors class, Material class, ShapeOfBody class, Temperature class, and

Vessel class (Figure 4.64). Any core class or subclass described in the TAO CI ontology is defined in OWL as owl:class, which is a subclass of owl:Thing.

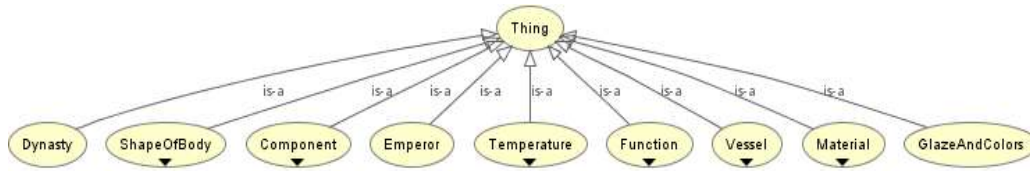


Figure 4. 64. The core class of TAO CI ontology.

The Vessel class is essential in the TAO CI ontology. It has different types of vessel classes, such as Box class, Bowl class, Basin class, Vase class, and Cup class (Figure 4.65). The different types of vases are defined as a subclass of Vase class. The subclass of Vase class has 34 classes and 34 different types of Chinese ceramic vases (Figure 4.66).

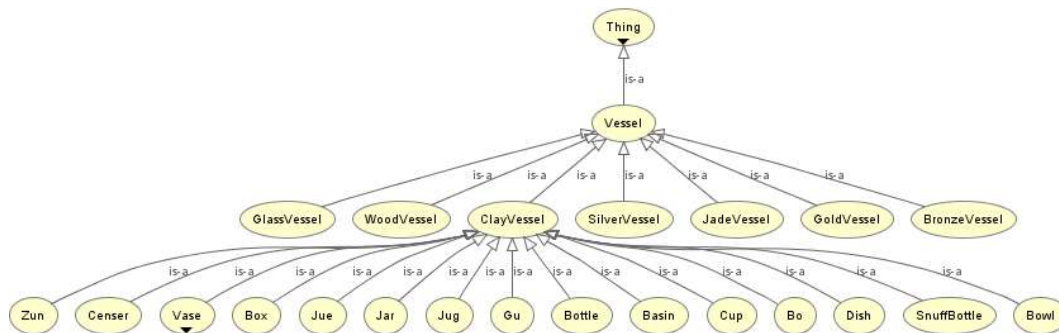


Figure 4. 65. The Vessel class of TAO CI ontology.

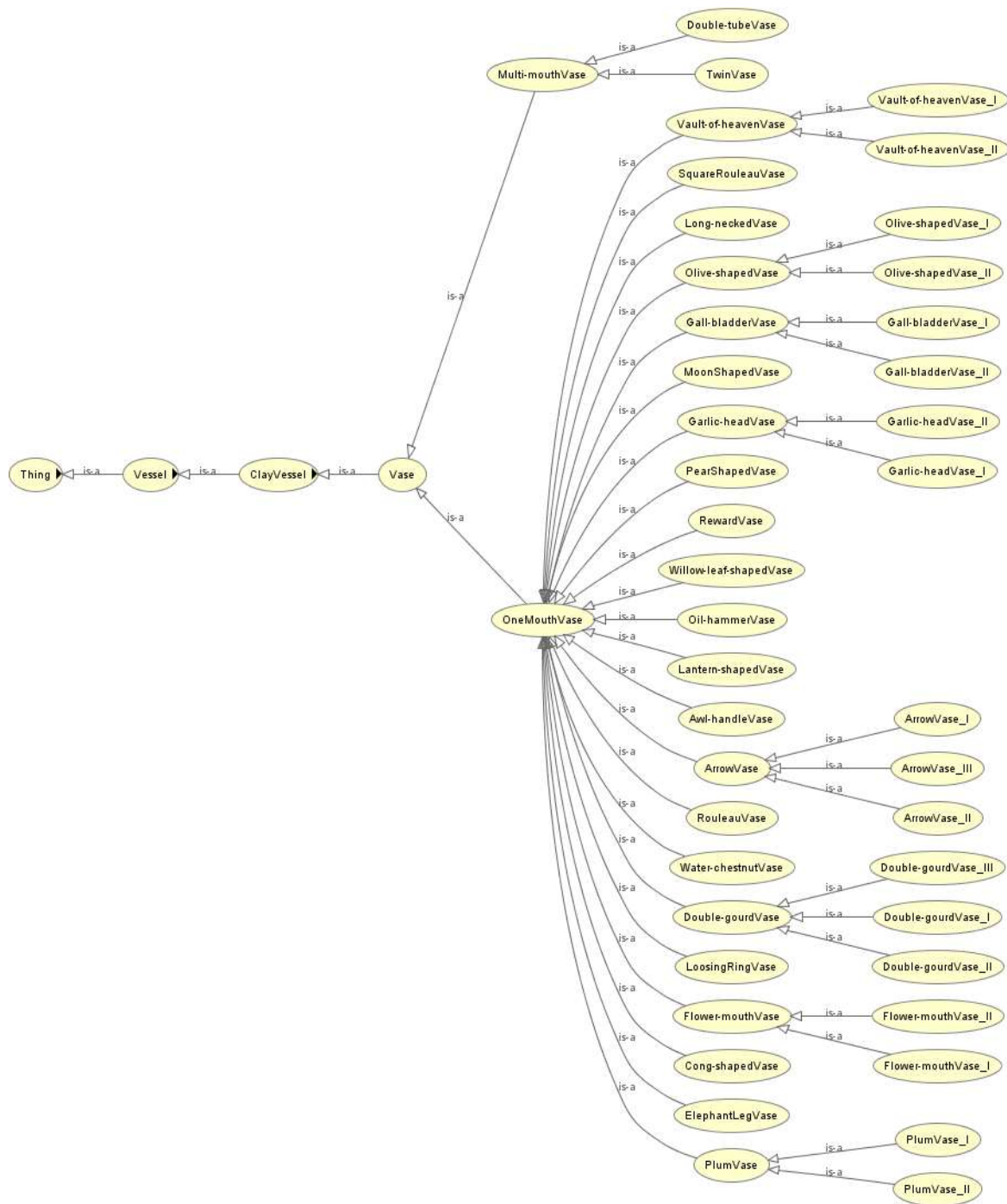


Figure 4. 66. The hierarchy of subclasses of Vase class in TAO CI ontology.

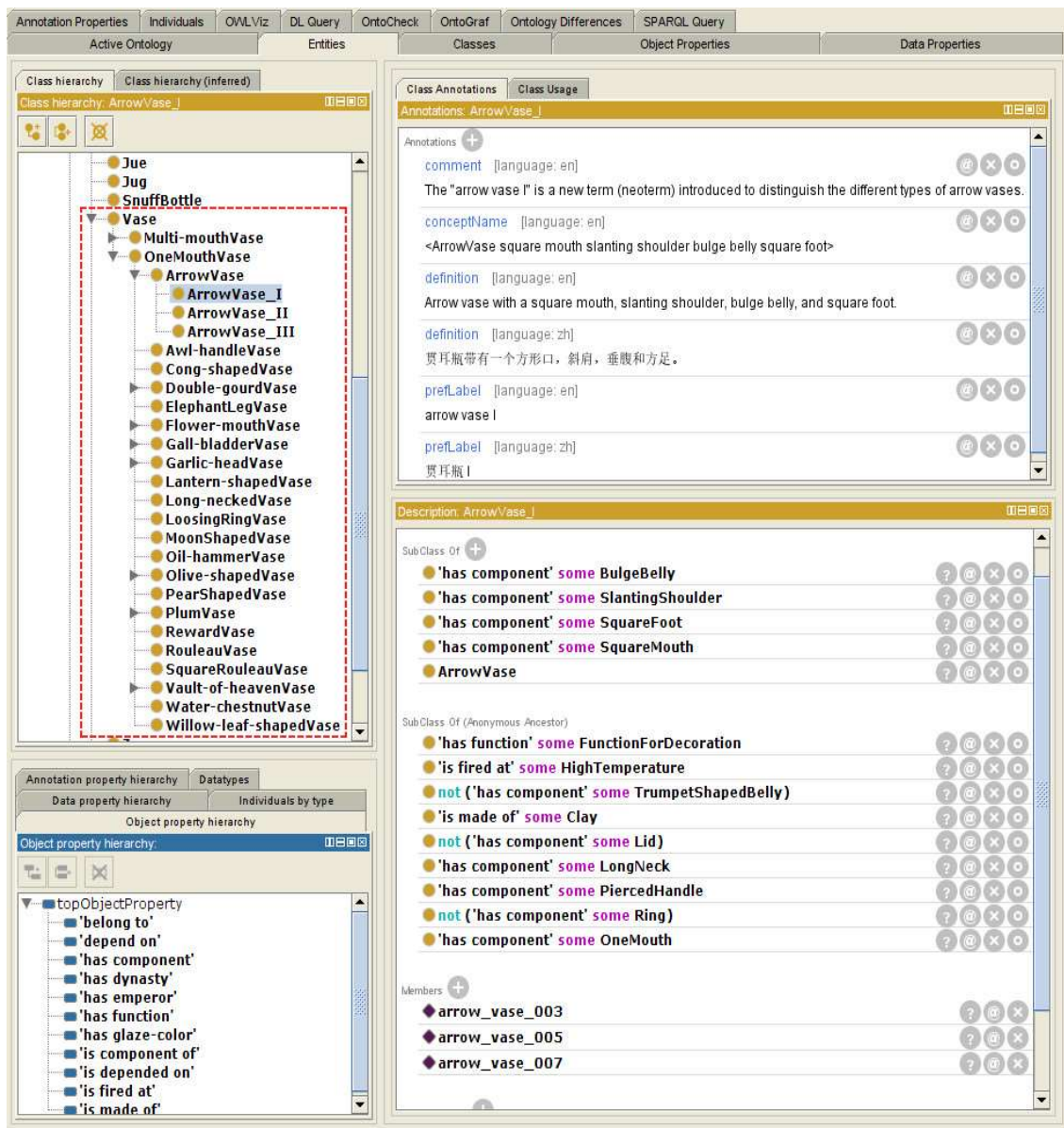


Figure 4. 67. An example of vase expression in OWL

Let us see an example. The concept denoted by the term “arrow vase I” (Figure 4.67), whose definition in natural language is “vase with a square mouth, long neck, slanting shoulder, pierced handle, bulge belly, and square foot”, is defined by the set of essential characteristics: $\{ /ArrowVase/, /square\ mouth/, /long\ neck/, /slanting\ shoulder/, /pierced\ handle/, /bulge\ belly/, /square\ foot/ \}$. It is represented by the ArrowVase_I class defined in OWL as a subclass (rdfs:subClassOf) of:

- ArrowVase
- hasComponent some SquareMouth
- hasComponent some LongNeck
- hasComponent some SlantingShoulder
- hasComponent some PiercedHandle

- hasComponent some BulgeBelly
- hasComponent some SquareFoot

3.2 Property

The property includes the object property and the data property. The object property includes belongTo, dependOn, hasFunction, hasComponent, hasGlaze-Color, hasDynasty, hasEmperor, isComponentOf, isDependedOn, isFiredAt, and isMadeOf. The domain and range of object properties are in table 12.

Table 12. The domain and range of object properties.

Object property	Domain	Range
belongTo	otc:Emperor	otc:Dynasty
isDependedOn	otc:Handle	otc:Ring
dependOn	otc:Ring	otc:Handle
hasFunction	otc:Vessel	otc:Function
hasComponent	otc:Vessel	otc:Component
isComponentOf	otc:Component	otc:Vessel
hasGlaze-color	otc:Vase	otc:GlazeAndColor
hasDynasty	otc:Vessel	otc:Dynasty
hasEmperor	otc:Vessel	otc:Emperor
isFiredAt	otc:ClayVessel	otc:Temperature
isMadeOf	otc:Vessel	otc:Material

The data property includes bellyNumber, decoration, diameterOfFoot, height, kiln, diameterOfMouth, mouthNumber, and museum. Their domain and range are in table 13.

Table 13. The domain and range of data properties.

Data property	Domain	Range
numberOfBelly	otc:Vessel	integer
isDecoratedBy	otc:Vessel	string
diameterOfMouth	otc:Vase	decimal

height	otc:Vase	decimal
isProducedIn	otc:ClayVessel	string
diameterOfFoot	otc:Vase	decimal
numberOfMouth	otc:Vessel	integer
isCollectedIn	otc:Vessel	string

3.3 Annotation

Annotations allow to enrich the description of the ontology and thus facilitate its understanding and reuse. The RDFS, DC, FOAF, and SKOS vocabularies are used to express metadata and the linguistic dimension associated to a concept (dc:publisher, dc:license, dc:creator, skos:prefLabel, skos:altLabel, skos:definition, rdfs:comment) as well as to express linking and mapping to external resources (rdfs:seeAlso, skos:broadMatch, skos:exactMatch). For example, the individual arrow vase 001 is described as follows (Figure 4.68).



```

<owl:NamedIndividual rdf:about="&OTContainer;arrow_vase_002">
  <rdf:type rdf:resource="&OTContainer;ArrowVase_III"/>
  <diameterOfFoot>18</diameterOfFoot>
  <isCollectedIn>THE PALACE MUSEUM</isCollectedIn>
  <numberOfMouth>1</numberOfMouth>
  <skos:prefLabel xml:lang="en">blue-and-white arrow vase painted
  with lotus flowers, Qianlong mark of Qing dynasty</skos:prefLabel>
  <isDecoratedBy>lotus flowers pattern</isDecoratedBy>
  <height>55</height>
  <diameterOfMouth>11</diameterOfMouth>
  <skos:prefLabel xml:lang="zh">清乾隆青花荷莲纹贯耳瓶</skos:prefLabel>
  <hasEmperor rdf:resource="&OTContainer;Qianlong"/>
  <hasDynasty rdf:resource="&OTContainer;Qing"/>
  <hasGlaze-Color rdf:resource="&OTContainer;blue-and-white"/>
  <isMadeOf rdf:resource="&OTContainer;clay"/>
  <foaf:depiction rdf:resource="https://www.dpm.org.cn/uploads/
  Picture/dc/57102.jpg"/>
  <rdfs:seeAlso rdf:resource="https://www.dpm.org.cn/collection/
  ceramic/227893.html?hl=%E8%B4%AF%E8%80%B3%E7%93%B6"/>
</owl:NamedIndividual>

```

Figure 4. 68. Arrow vase 001.

Chapter 4. Ontology Evaluation

This work aims to construct a knowledge representation model to describe and classify the ceramic vases of Chinese museum collections of the Ming and Qing dynasties, and to provide a formal expression of cultural heritage data for linking open data, and to build a multi-linguistic term knowledge base to communicate for different country experts. The last stage of ontology building is ontology evaluation whose main goal is “to assess the quality and correctness of the obtained ontology” (Sabou & Fernandez, 2012). We used reasoners, two online platforms, and queried the ontology using the Competency Questions defined in table 4.

Reasoners has two main services: one is to test whether or not one class is a subclass of another class; another service is to consistency checking (Horridge et al., 2004, p. 48). For the first service, it is possible to compute the inferred ontology class hierarchy. For the second service, it is to check whether or not the class can have any instances (Horridge et al., 2004, p. 48). Consistency checking is often used for ontology evaluation. Protégé provides the plugin of reasoners called by Fact++. In Protégé, the “manually constructed” class hierarchy is called the asserted hierarchy. The class hierarchy that is automatically computed by the reasoned is called the inferred hierarchy (Horridge et al., 2004, p. 48). If a class is inconsistent, it’s icon will be highlighted in red during reasoning (Horridge et al., 2004, p. 48). In our ontology, we did not find any inconsistency, when we reasoned by the Fact++. So the consistency of the TAO CI ontology is better.

The second work is to submit TAO CI ontology to OOPS!, which is an online tool for validating the ontology against the most common modeling pitfalls (Poveda-Villalón et al., 2014). OOPS! supplies three indicators: critical, valuable, and minor for each pitfall. For the critical, it is crucial to correct the pitfall. Otherwise, it could affect the ontology consistency, reasoning, and applicability. For the important, though not critical for ontology function, it is important to correct this type of pitfall. For the minor, it is not a problem, but we will make the ontology nicest by correcting it. In the case of TAO CI ontology, OOPS! did not detect any critical and important pitfalls. OOPS! has detected only minor pitfalls for the TAO CI ontology (e.g., P08 “Missing annotations”, P13 “Inverse relationships not explicitly declared”).

We also submitted the TAO CI ontology to OntoMetrics that is an online platform to calculate more advanced ontology metrics (Lantow, 2016). Table 14 shows some schema metrics¹³¹ and knowledge-base metrics result in ontology clarity and conciseness (Vrandečić, 2010).

Table 14. TAO CI advanced metrics.

Metric	Value
Attribute richness	0.048485
Inheritance richness	2.715152
Relationship richness	0.334324

¹³¹ https://ontometrics.informatik.uni-rostock.de/wiki/index.php/Schema_Metrics

Class/Relation ratio	0.245171
Average population	0.8
Class richness	0.321212

Most of the scores are very low. That is due to:

1. The implementation of essential characteristics in Description Logic. Essential characteristics are translated as classes without any attributes (attribute richness);
2. The primary goal of the TAO CI ontology is a classification of vases, neither representing relationships between vases and other artifacts (relationship richness, class/relation ratio) nor populating the ontology with individuals (average population, class richness).

Evaluation of criteria strongly depends on the goals of the ontology and implementation choices: “a good ontology does not perform equally well with regard to all criteria” (Vrandečić, 2009). Let us also note that, regarding our objectives (classification and terminology), the TAO CI ontology well covers the domain in the sense that each individual falls into a concept (classification), and each concept is clearly defined as a unique combination of essential characteristics (terminology).

The last validation concerns the answers to the Competency Questions. All of them are satisfied. Figures 4.69 present 3 competency questions translated into SPARQL and the returned results.

Q1: What are the types of vase?

Q2: What are the Chinese term and English terms of subclasses of the class Vase?

Q3: What are the Chinese terms, English terms, and images of individuals?

Q1	Q2	Q3
<pre> PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> PREFIX owl: <http://www.w3.org/2002/07/owl#> PREFIX skos: <http://www.w3.org/2004/02/skos/core#> PREFIX otc: <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#> SELECT ?x ?name WHERE { ?x rdfs:subClassOf * otc:Vase. ?x skos:prefLabel ?name. FILTER (lang(?name) = 'zh') } </pre>	<pre> PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> PREFIX owl: <http://www.w3.org/2002/07/owl#> PREFIX skos: <http://www.w3.org/2004/02/skos/core#> PREFIX otc: <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#> SELECT distinct ?name_en ?name_zh WHERE { ?x rdfs:subClassOf * otc:Vase. ?x skos:prefLabel ?name_en. ?x skos:prefLabel ?name_zh. FILTER (lang(?name_en) = 'en') FILTER (lang(?name_zh) = 'zh') } </pre>	<pre> PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> PREFIX owl: <http://www.w3.org/2002/07/owl#> PREFIX skos: <http://www.w3.org/2004/02/skos/core#> PREFIX foaf: <http://xmlns.com/foaf/0.1/> SELECT distinct ?x ?name_eng ?name_zh ?img WHERE { ?x rdf:type owl:NamedIndividual. ?x skos:prefLabel ?name_eng. ?x skos:prefLabel ?name_zh. FILTER (lang(?name_eng) = 'en'). FILTER (lang(?name_zh) = 'zh'). ?x foaf:depiction ?img } </pre>

Figure 4. 69. The SPARQL of three questions.

The results of the above three questions are shown in Figure 4.70. We just list a part of the results.

x	name
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Awl-handle-shapedVase	"耑把瓶"@zh
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase_I	"耑耳瓶"@zh
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase_II	"耑耳瓶"@zh
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase_III	"耑耳瓶"@zh
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#CircleRouleauVase	"款博瓶"@zh
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Cong-shapedVase	"琮式瓶"@zh
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#CylindricalVase	"筒瓶"@zh
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Double-tubeVase	"多管瓶"@zh
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#DoubleGourdShapedVase_I	"葫芦瓶"@zh

Result of Q1

name_en	name_zh
"arrow vase"@en	"耑耳瓶"@zh
"awl-handle-shaped vase"@en	"耑把瓶"@zh
"circle rouleau vase"@en	"款博瓶"@zh
"Cong-shaped Vase"@en	"琮式瓶"@zh
"cylindrical vase"@en	"筒瓶"@zh
"double-tube vase"@en	"多管瓶"@zh
"double gourd shaped vase"@en	"葫芦瓶"@zh
"gall-bladder Vase"@en	"胆式瓶"@zh

Result of Q2

x	name_eng	name_zh	img
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#arrow_vase_001	"blue-and-white arrow vase painted lotus flowers and eight emblems, Qianlong mark of Qing dynasty"@en	"清乾隆青花莲 花托八宝纹箭 瓶"@zh	https://www.dhm.org.cn/uploads/Picture/dh/3664.jpg
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#arrow_vase_002	"blue-and-white arrow vase painted with lotus flowers, Qianlong mark of Qing dynasty"@en	"清乾隆青花莲 花箭瓶"@zh	https://www.dhm.org.cn/uploads/Picture/dh/57102.jpg
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#arrow_vase_003	"d'ong green glaze arrow vase, Kuanlong mark of Qing dynasty"@en	"清康熙绿釉 箭瓶"@zh	https://www.dhm.org.cn/uploads/Picture/dh/16328.jpg
http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#arrow_vase_004	"fame glaze arrow vase, Qianlong mark of Qing dynasty"@en	"清乾隆黄釉 箭瓶"@zh	https://www.dhm.org.cn/uploads/Picture/dh/2384.jpg

Result of Q3

Figure 4. 70. The result of the questions.

Conclusion

This part presented the ontoterminology of Chinese ceramic vessels: the term-and-characteristic guided method, linguistic dimension, and conceptual dimension.

The term-and-characteristic guided method chapter introduced the principal idea of the term-and-characteristic guided approach, which follows the ISO principles of Terminology (ISO 1087-1 and 704) and compares with other methodologies of constructing ontology. The principal work in this chapter is the description of the workflow of the term-and-characteristic guided method, which guides domain experts to develop the domain ontology and reduces the dependence on formal languages and logic. Also, presenting the method of identifying essential characteristics and combining the essential characteristics.

The TAO CI ontology authoring chapter described the process of ontology creation, which included the objectives, competency questions, linguistic dimension, conceptual dimension, building ontology by Protégé, and integration. The linguistic dimension section presented the linguistic information of vessels and vases, which include identifying the terms and objects denoted by the terms. The conceptual dimension section stated the method of identifying the essential characteristics and descriptive characteristics. In the domain of ceramic vases, there are nine descriptive characteristics. The section of ontology building in Protégé presented the TAO CI ontology, which was translated as OWL.

The TAO CI ontology description chapter stated the classes, properties, and annotation when we translated ontology in OWL. Last, the ontology was evaluated by means of two online tools and competency questions. The OOPS tool has detected only minor pitfalls for the TAO CI ontology (e.g., P08 “Missing annotations”, P13 “Inverse relationships not explicitly declared”). The score of OntoMetrics is low, but explanations were offered as to why that is.

Part V: APPLICATION: TAO CI WEBSITE

Chapter 1. Structure of the Website

The TAO CI website has been published at <http://www.dh.ketrc.com/>. The website was built in order to host the TAO CI project ontology and the e-dictionary based on the TAO CI ontology. The website is presented in what follows.

The website of the TAO CI project is developed following the Browser/Server (B/S) architecture model, which includes three layers: user layer, middle layer, and the data layer (Figure 5.1). The user layer provides the user request to the web server. The inner layer provides queries according to user requests. In this layer, combining JavaScript and SPARQL, end up the query requests. The Tao Ci ontology is found on the data layer, which provides the data. The ontology is used to link data from different resources, such as museums, linked open data cloud, and other file systems.

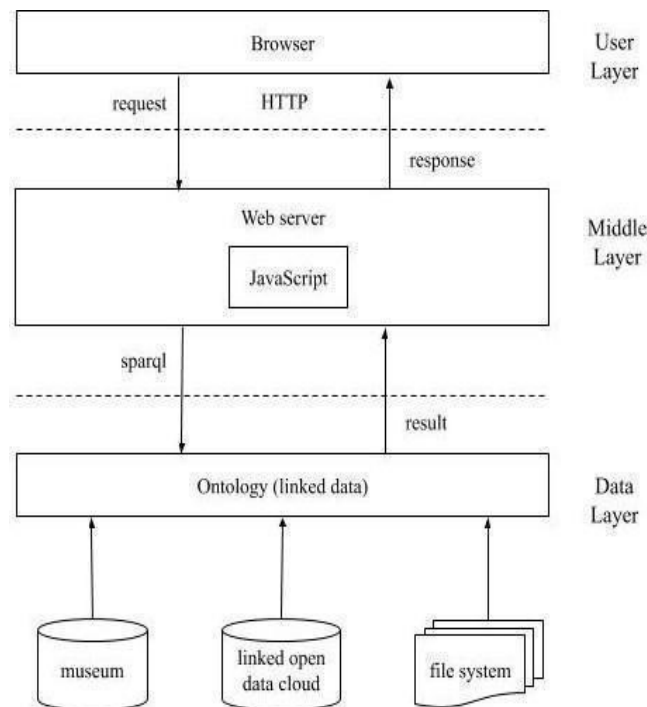


Figure 5. 1. The structure of the website.

Chapter 2. Function of the Website

The website of the Tao Ci project includes four functions: Home, Ontology, E-dictionary, Dataset, and Contact. Figure 5.2 shows the function structure of the website.

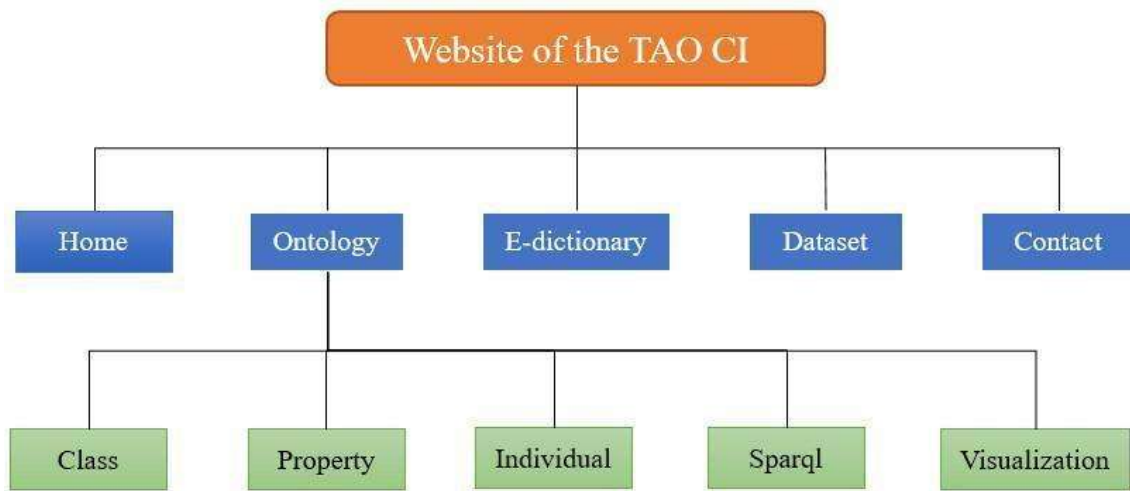


Figure 5. 2. The function structure of the website.

2.1 Home

The home page helps readers to know about the TAO CI project (Figure 5.4). It introduces the necessary information on the TAO CI project, i.e., that it is a collaborative project dedicated to defining the concept denoted by Chinese ceramics vessel terms. It also includes the purpose of the TAO CI project is to provide a model of publishing open data for museums and link data of the Chinese ceramics and build a multi-linguistic e-dictionary of Chinese ceramics to communicate with archeologists in the world. The collaborating institutions include The Condillac Group of LISTIC Lab of the University Savoie Mont-Blanc and the School of Computer Science of Liao Cheng University. In addition, the home page lists the published papers resulting from research on the TAO CI project. Finally, the website also includes a mention of the funding received by the TAO CI project by the China Scholarship Council (CSC) from November 2017 to November 2020.

2.2 Ontology

The ontology page is used to display the TAO CI ontology, which includes Classes, Properties, Individuals, Sparql, and Visualization (Figure 5.3). The ontology display is based on the frame of jOWL, which provides the library of parsing ontology in javascript. The visualization is based on the WebVOWL tool.

Class. It displays ceramic vase classes. It mainly consists of four parts (Figure 5.5). Part 1 displays all the classes of Tao Ci ontology. Part 2 provides the search function. Part 3 displays the hierarchical relationship of the class that is selected in part 1. It provides two different styles that are tree structure and navigation bar. Part 4 shows the selected class information, such as class name, concept name, term, relationship, and individual. For example, Figure 5.5 shows Awl-handle Vase class information on the part 3 and 4. Part 3 displays the hierarchy of the Awl-handle vase class. Part 4 shows the preferred term is “awl-handle vase” in English and “锥把瓶” in Chinese.

Property. It shows the object properties, data properties, and their domain and range (Figure 5.6). For example, the object property *isDependedOn* is inverse of *dependOn*. The domain of “*isDependedOn*” is the *Handle* class, and the range is the *Ring* class.

Individual. It displays all the Tao Ci ontology individuals and the relevant information. Part 1 shows the individuals. Part 2 displays all the information on the individual. For example, Figure 5.7 shows the olive-shaped vase 002 individual of the Olive-shaped Vase I class. Part 2 shows the information on the olive-shaped vase 002 including all data properties (such as the museum, diameter, and *preLabel*) and object properties (such as *isMadeOf*, *hasDynasty*, *hasGlaze-color*). The image is taken from the museum that collected this individual.

SPARQL. It supplies the query function. It is based on the description of logic. For example, Figure 5.8 shows the all object property in the Tao Ci ontology. If the reader wants to use SPARQL endpoint, the URL to use is as follows: “<http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl>”.

Visualization. The purpose of a visualization is to display data information more intuitively. WebVOWL is a useful tool to display ontology. Therefore, in our system, we used WebVOWL to visualize our ontology.



Figure 5. 3. The ontology of the website.

OTContainer

O: Ontology T: Terminology
C: China and Container

[Home](#) [Ontology](#) [E-dictionary](#) [Dataset](#) [Contact](#)

TAO CI Project

The TAO CI Project is a collaborative project dedicated to defining the concept denoted by Chinese ceramics vessel terms. The purpose of TAO CI project is to provide a model of publishing open data for museum and link data of the Chinese ceramics and build a multi-linguistics e-dictionary of Chinese ceramics to communicate with archeologists in the world.

The TAO CI project is based on the ISO 704 and ISO 1087 to develop this model. It is an interdisciplinary project, which is related to Archeology (Cultural Heritage),Linguistic (Terminology),Artificial Intelligence (Knowledge Representation), Semantic Web (Linked Data). The methodology of the TAO CI project is the ontoterminology that is a terminology whose conceptual system is a formal ontology.

Scientific Committe

The scientific committee is based on the KETRC (Knowledge Engineering & Terminology Research Center) research center, which is set up in 2017 between Liaocheng University (China) and University Savoie Mont-Blanc (France).

- Christophe Roche (France)
- Tong Wei (China)
- Papadopoulou Maria (Greece)
- Yangli Jia (China)
- Julien Roche (France)
- Zhenling Zhang (China)

Papers and Presentations

- 2020: Tong WEI, "Ontology Specification & Competency Questions", KETRC online meeting, France
- Tong WEI, C.Roche, Yangli Jia, M. Papadopoulou (2020.11). "Terminologie et Ontologie pour l'Héritage Culturel : Le projet TAO CI", TOTh 2020, Terminology & Ontology : Theories and applications, Chambéry (France)
- Tong WEI, C.Roche, Yangli Jia, M. Papadopoulou (2020.11). "An Ontology of Chinese Ceramic Vases", 12th International Conference on Knowledge Knowledge Engineering and Ontology Development.

Support



China Scholarship Council

The TAO CI project was funded by China Scholarship Council from November 2017 to November 2020.

Collaborating Institutions



LISTIC

The Condillac Group of LISTIC Lab of University Savoie Mont-Blanc



Liao Cheng University

The School of Computer Science of Liao Cheng University

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Figure 5. 4. The Homepage of the website.

OTContainer
 O: Ontology T: Terminology
 C: China and Container

Home Ontology E-dictionary Dataset Contact

Arrow Vase, Arrow Vase I, Arrow Vase II, Arrow Vase III, Awl-handle Vase, Basin, Belly, Bending Neck, Bo, Bottle, Bottom, Bowl, Box, Bronze, Bronze Vessel, Brush Washer Shaped Mouth, Bulge Belly, Censer, Circle Mouth, Circle Shoulder, Clay, Clay Vessel, Component, Concave Foot, Cong-shaped Vase, Convergence Foot, Convergence Mouth, Cup, Cylindrical Belly, Deep Belly, Dish, Double-gourd Vase, Double-gourd Vase I, Double-gourd Vase II, Double-gourd Vase III, Double-tube Vase, Dragon-massk Handle, Dragon Shaped Handle, Drooping Belly, Dynasty, Elephant Leg Vase, Elephant Shaped Handle, Emperor, Everted-rim Mouth, Fish Shaped Handle, Flat Belly, Flat Bottom, Flat Shoulder, Flower-mouth Vase, Flower-mouth Vase I, Flower-mouth Vase II, Flower Shaped Mouth, Folding Shoulder, Foot, Function, Function For Cooking, Function For Decoration, Function For Drawing Water, Function For Drinking, Function For Eating, Function For Sacrifice, Function For Snuff, Function For Storing Liquid, Function For Storing Solid, Function For Washing, Gall-bladder Vase, Gall-bladder Vase I, Gall-bladder Vase II, Garlic-head Vase, Garlic-head Vase I, Garlic-head Vase II, Garlic Shaped Mouth, Glass, Glass Vessel, Glaze-Color, Globular Belly, Gold, Gold Vessel, Gourd Shaped Belly, Gu, Halberd Shaped Handle, Handle, High Foot, High Temperature, Jade, Jade Vessel, Jar, Jue, Jug, Lantern-shaped Vase, Large Mouth, Lid, Lip Mouth, Long-necked Vase, Long Neck, Loosing Ring Vase, Low Foot, Low Temperature, Material, Moon Shaped Vase, Mouth, Multi-mouth Vase, Multi-mouths, Multi-prism Belly, Neck, Oblate Belly, Oil-hammer Vase, Olive-shaped Vase, Olive-shaped Vase I, Olive-shaped Vase II, One Mouth, One Mouth Vase, Open Mouth, Outward Foot, Outward Mouth, Pear Shaped Belly, Pear Shaped Vase, Phoenix Shaped Handle, Pierced Handle, Plate Shaped Mouth, Plum Vase, Plum Vase I, Plum Vase II, Reward Vase, Ribbon Shaped Handle, Ring, Ring Foot, Rouleau Vase, Round Belly, Ru-Yi Shaped Handle, Shallow Belly, Shape Of Body, Short Neck, Shoulder, Silver, Silver Vessel, Slanting Shoulder, Slender Neck, Small Mouth, Snuff Bottle, Spheroid Belly, Spout, Square Belly, Square Foot, Square Mouth, Square Rouleau Vase, Straight Foot, Straight Mouth, Straight Neck, Swelling Body Tapering Downward, Temperature, Trumpet Shaped Belly, Trumpet Shaped Mouth, Twin Vase, Vase, Vault-of-heaven Vase, Vault-of-heaven Vase I, Vault-of-heaven Vase II, Vessel, Water-chestnut Vase, Wide Neck, Willow-leaf-shaped Vase, Wood, Wood Vessel, Zun

Tree Structure: Navigation Bar:

Enter Search Terms here:

- Vessel
 - Clay Vessel
 - Vase
 - One Mouth Vase
 - Awl-handle Vase

Class Name: Awl-handle Vase
Concept Name: <OneMouthVase without lid small mouth slender neck long neck slanting shoulder without handle without ring globular belly flat bottom ring foot>
Comment: The vase is so named because of its shape of awl-handle.
Terms(preLabel): awl-handle vase @en | 锺把瓶 @zh
Terms(altLabel):
Individuals: awl-handle-shaped vase 001
Relations:

- has component: [Slender Neck](#)
- has component: [Globular Belly](#)
- has component: [Flat Bottom](#)
- has component: [Ring Foot](#)
- has component: [Small Mouth](#)
- has component: [Slanting Shoulder](#)
- has component: [Long Neck](#)
- is fired at: [High Temperature](#)
- has function: [Function For Decoration](#)
- is made of: [Clay](#)

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Figure 5. 5. The classes of ontology.

OTContainer
 O: Ontology T: Terminology
 C: China and Container

Home Ontology E-dictionary Dataset Contact

ObjectProperty	DataProperty
belong to, depend on, has component, has dynasty, has emperor, has function, has glaze-color, is component of, is depended on, is fired at, is made of	creator, publisher, license, conceptName, sameAs, altLabel, broadMatch, definition, exactMatch, prefLabel, depiction, diameter of foot, diameter of mouth, height, is decorated by, number of belly, number of mouth

Description of is depended on

It is inverse functional with 'depend on'.
Terms: is Depended On
Domain: <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle>
Range: <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Ring>

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Figure 5. 6. The properties of the Tao Ci ontology.

OTContainer

O: Ontology T: Terminology
C: China and Container

[Home](#) [Ontology](#) [E-dictionary](#) [Dataset](#) [Contact](#)

[Chenghua](#), [Chongzhen](#), [Daoguang](#), [Guangxu](#), [Hongwu](#), [Hongzhi](#), [Jiajing](#), [Jiaqing](#), [Kangxi](#), [Longqing](#), [Qianlong](#), [Shunzhi](#), [Tianqi](#), [Tongzhi](#), [Wanli](#), [Xianfeng](#), [Xuande](#), [Xuanton](#), [Yongle](#), [Yongzheng](#), [Zhengde](#), [Furnace Jun glaze](#), [Lang Yao Red glaze](#), [ash glaze](#), [blue-and-white](#), [blue glaze](#), [celadon glaze](#), [clear glaze](#), [cloisonne](#), [coral-red glaze](#), [crystalline glaze](#), [dong green glaze](#), [doucai](#), [famille rose](#), [five-color](#), [flame glaze](#), [flow blue](#), [ge glaze](#), [iron-red on green glaze](#), [over glaze](#), [peach bloom](#), [ruby red glaze](#), [sky blue glaze](#), [slip glaze](#), [under glazing](#), [underglaze red](#), [white glaze](#), [yellow glaze](#), [Ming](#), [Qing](#), [Ru-yi handle](#), [arrow vase 001](#), [arrow vase 002](#), [arrow vase 008](#), [arrow vase 003](#), [arrow vase 005](#), [arrow vase 007](#), [arrow vase 004](#), [arrow vase 006](#), [awl-handle-shaped vase 001](#), [bronze](#), [circle rouleau vase 001](#), [circle rouleau vase 002](#), [circle rouleau vase 003](#), [clay](#), [cong-shaped vase 001](#), [cong-shaped vase 002](#), [cong-shaped vase 003](#), [cylindrical vase 001](#), [cylindrical vase 002](#), [double-gourd shaped vase 005](#), [double gourd shaped vase 001](#), [double gourd shaped vase 002](#), [double-tube vase 001](#), [double gourd shaped vase 003](#), [double gourd shaped vase 006](#), [double gourd shaped vase 004](#), [dragon-mask handle](#), [dragon shaped handle](#), [elephant shaped handle](#), [fish shape handle](#), [gall-bladder vase 001](#), [gall-bladder vase 002](#), [gall-bladder vase 003](#), [gall-bladder vase 004](#), [garlic-head vase 001](#), [garlic-head vase 003](#), [garlic-head vase 005](#), [garlic-head vase 006](#), [garlic-head vase 002](#), [garlic-head vase 004](#), [glass](#), [gold](#), [halberd shape handle](#), [jade](#), [lantern-shaped vase 001](#), [lantern-shaped vase 002](#), [long-necked vase 001](#), [long-necked vase 002](#), [moon shape vase 001](#), [oil-hammer vase 001](#), [olive-shaped vase 001](#), [olive-shaped vase 002](#), [olive-shaped vase 003](#), [olive-shaped vase 004](#), [olive-shaped vase 005](#), [pear shaped vase 001](#), [pear shaped vase 002](#), [phoenix shaped handle](#), [pierced handle](#), [plum vase 001](#), [plum vase 002](#), [plum vase 003](#), [plum vase 004](#), [reward vase 001](#), [reward vase 002](#), [ribbon shape handle](#), [silver](#), [square rouleau vase 001](#), [twin vase 001](#), [vase with flower shape mouth 001](#), [vase with flower shape mouth 002](#), [vase with loosing ring 001](#), [vault-of-heaven vase 001](#), [vault-of-heaven vase 002](#), [vault-of-heaven vase 006](#), [vault-of-heaven vase 003](#), [vault-of-heaven vase 004](#), [vault-of-heaven vase 005](#), [water-chestnut vase 001](#), [willow-leaf-shaped vase 001](#), [wood](#)

Description of olive-shaped vase 002

owl:Class Olive-shaped Vase I

number of mouth 1

height 39.3

diameter of foot 12.3

diameter of mouth 10

prefLabel blue-and-white olive-shaped vase painted with peaches and bats, Yongzheng mark of Qing dynasty

is decorated by peaches and bats pattern

is collected in THE PALACE MUSEUM

prefLabel 清雍正青花桃蝠纹橄榄式瓶


has dynasty Qing

has emperor Yongzheng

has glaze-color blue-and-white

is made of clay

depiction <https://www.dpm.org.cn/Uploads/Picture/dc/154.jpg>



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Figure 5. 7. The individuals of the Tao Ci ontology.

OTContainer
O: Ontology T: Terminology
C: China and Container

Home Ontology E-dictionary Dataset Contact

Enter a query:
ObjectProperty(?a)

Results Number of results: 11

- ?a : belong to
- ?a : depend on
- ?a : has component
- ?a : has dynasty
- ?a : has emperor
- ?a : has function
- ?a : has glaze-color
- ?a : is component of
- ?a : is depended on
- ?a : is fired at
- ?a : is made of

Syntax

- Type(?a, ?b)
- PropertyValue(?a, ?b, ?c)
- Class(?a)
- ObjectProperty(?a)
- DatatypeProperty(?a)

Explain:

1. Get all individuals of the class "Vase".
Type(?individual, http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vase)
2. Get all property relation of the class "Vase".
PropertyValue(http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vase, ?b, ?c)
3. Get all Class.
Class(?a)
4. Get all object properties.
ObjectProperty(?a)
5. Get all data type property.
DatatypeProperty(?a)

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Figure 5. 8. The Sparql of the Tao Ci ontology.

2.3 E-dictionary

The e-dictionary of Chinese ceramic vases is based on the TAO CI ontology, which provides the data and term for readers. The e-dictionary aims to provide a terminological knowledge base for different archeology to communicate in the world. The e-dictionary is composed of seven parts (Figure 5.9).

1. Part 1 shows the class name in the TAO CI ontology. It is composed of different types of Chinese ceramic vases. For example, the “Garlic-head Vase I” class.
2. Part 2 is about the preferred term in English and Chinese, such as “garlic-head vase I” in English and “蒜头瓶” in Chinese.
3. Part 3 is to display the alternative terms in English and Chinese, if the concept has alternative terms. For example, the “garlic vase I” and “garlic-mouth vase”.

4. Part 4 states the concept name, which is the name of concepts in the concept system. For example, the concept name of “garlic-head vase I” is <Garlic-headVase short neck circle shoulder ru-yi shaped handle globular belly> in the concept system.

5. Part 5 is about the definition of terms in English and Chinese. The definition of the term is written in the natural language according to the formal definition of the TAO CI ontology. For example, the definition of the “garlic-head vase I” is “Garlic-head vase with a short neck, circle shoulder, globular belly, and ru-yi shaped handles” in English, and “蒜头瓶带有短颈，圆肩，球形腹和如意耳” in Chinese.

6. Part 6 aims to help readers to understand the terms by explaining the term whether it is a new term.

7. Part 7 lists the essential characteristics of identifying the concept denoted by the term. It does not list the essential characteristics of the generic concepts.

8. Part 8 provides the reference links for other information.

9. Part 9 offers the images of individuals to help readers to identify the individual that falls under the concept denoted by the term. These images come from the site of the Chinese museum.

This e-dictionary not only provides a bilingual terminology of the domain, but also provides essential characteristics of the heritage objects denoted by the terms as well, as images of vases.

OTContainer

O: Ontology T: Terminology
C: China and Container

Home
Ontology
E-dictionary
Dataset
Contact

Arrow Vase

Arrow Vase I

Arrow Vase II

Arrow Vase III 1

Cong-shaped Vase

Double-gourd Vase

Double-gourd Vase I

Double-gourd Vase II

Double-gourd Vase III

Double-tube Vase

Elephant Leg Vase

Flower-mouth Vase

Flower-mouth Vase I

Flower-mouth Vase II

Gall-bladder Vase

Gall-bladder Vase I

Gall-bladder Vase II

Garlic-head Vase

Garlic-head Vase I

Garlic-head Vase II

Lantern-shaped Vase

Long-necked Vase

Loosing Ring Vase

Moon Shaped Vase

Oil-hammer Vase

Olive-shaped Vase

Olive-shaped Vase I

Olive-shaped Vase II

Pear Shaped Vase

Plum Vase

Plum Vase I

Plum Vase II

Reward Vase

Rouleau Vase

Square Rouleau Vase

Twin Vase

Vault-of-heaven Vase

Vault-of-heaven Vase I

Vault-of-heaven Vase II

Water-chestnut Vase

Willow-leaf-shaped Vase

Garlic-head Vase I

Terms (prefLabel):

garlic-head vase I [EN] 2

蒜头瓶 I [ZH]

Terms (altLabel):

garlic vase I @en | garlic-mouth vase I @en | 3

Concept Name:

<Garlic-headVase short neck circle shoulder ru-yi shaped handle globular belly> 4

Definition:

Garlic-head vase with a short neck, circle shoulder, globular belly, and ru-yi shaped handles.[EN]

蒜头瓶带有短颈，圆肩，球形腹和如意耳。 [ZH] 5

Comment:

The "garlic-head vase I" is a new term (neoterm) introduced to distinguish the different types of a garlic-head vases. 6

Essential Characteristic


- has component: [/Ru-Yi Shaped Handle/](#)
- has component: [/Globular Belly/](#)
- has component: [/Short Neck/](#) 7
- has component: [/Circle Shoulder/](#)
- has function: [/Function For Decoration/](#)
- is fired at: [/High Temperature/](#)
- is made of: [/Clay/](#)

See also

<https://www.dpm.org.cn/collection/ceramic/227032.html> 8

<https://www.dpm.org.cn/collection/ceramic/227060.html>

9



Condillac group
KETRC (Knowledge Engineering Terminology Research Center)

Figure 5. 9. The E-dictionary.

Part VI: CONCLUSION & FUTURE WORK

Digital Humanities is an umbrella term which covers a lot of different disciplines from computer science and humanities. In the context of this work, we have focused on Chinese ceramic vessels mainly because they are among the most iconic artefacts of Chinese cultural heritage. Two dynasties were selected for their importance in regard to our topic. The Ming Dynasty (1368-1644) ceramics were famous for the boldness of their form and decoration, and the varieties of design, when the Qing dynasty (1644-1911) porcelain was famous for its polychrome decorations, delicately painted landscapes, and birds and flowers as well as multicolour enamel designs.

The very first issue that experts need to address in modeling data about cultural objects is terminology, i.e. identifying the terms denoting these objects and defining them in relation to the description of objects¹³².

The TAO CI project addressed this issue in the following three ways. The first one was to build a knowledge representation of Chinese ceramics of the Ming and Qing dynasties as a formal ontology. The second one was to define the corresponding terminology (i.e., list of terms) and provide a bilingual (Chinese-English) e-dictionary of ceramic vases. The last one was to open the terminology and the ontology to the Semantic Web. The result is the first ontoterminology (terminology whose conceptual system is a formal ontology) of Chinese ceramics of the Ming and Qing Dynasties.

Our work is multidisciplinary. It combines Artificial Intelligence (Knowledge Representation, Ontology), Linguistics (Terminology, e-Dictionaries), Semantic Web (Linked Open Data, Knowledge Graphs) and Digital Humanities (Cultural Heritage, Chinese Ceramic Vases).

Our work relies, first on a strong hypothesis which states that “a term is a verbal designation of a concept”. Second on the principle of taking into account the way of thinking of domain experts for the conceptualization of the domain. Third, on building an e-Dictionary and a dedicated web site. At every stage, we have taken into consideration both the ISO standards in Terminology (ISO 1087 and ISO 704) and the W3C Standards for the Semantic Web (RDF/OWL).

The statement “a term is a verbal designation of a concept” implies a clear distinction between the two dimensions which compose all terminologies: the linguistic one and the conceptual one. The focus is put not on the meaning of terms in linguistic discourses but on the concepts denoted by terms. This raises a lot of research questions about the “nature” of concept and its relationships with the linguistic dimension, for example if it is possible to “generate” a definition of term in natural language from the formal definition of concept. Among the research questions tackled in this work, let us quote two of them. The first one is about the “nature” of concept which has to reconcile different points of view from terminology, domain experts, and computational representation. The second one concerns the methodology of ontology building, which remains a challenge in knowledge engineering. For the latter point, the domain of application can bring useful indication and even methodological guidelines, relying both on the type of artefacts, e.g. their structure, and on morphological analysis of the Chinese terms.

¹³² Won-Yong Kim (1970), an archaeologist specialized in Asian archaeology, sums up the problem in his article entitled "On the standardization of Ceramic Terminology" published in the *Current Anthropology Journal* (Kim, 1970): "As Claerhout points out, standardization of the terminology for the shapes of ceramic vessels might be helpful. [...] I feel, nevertheless, that it would help if we could work out a list of standard vessel shapes, clearly defined and illustrated, and a set of terms for them that is perhaps entirely different from, and so cannot be confused with, the terms in common popular use"

Figure 1.1 sums up the different research topics we were working on, as well as their interconnections.

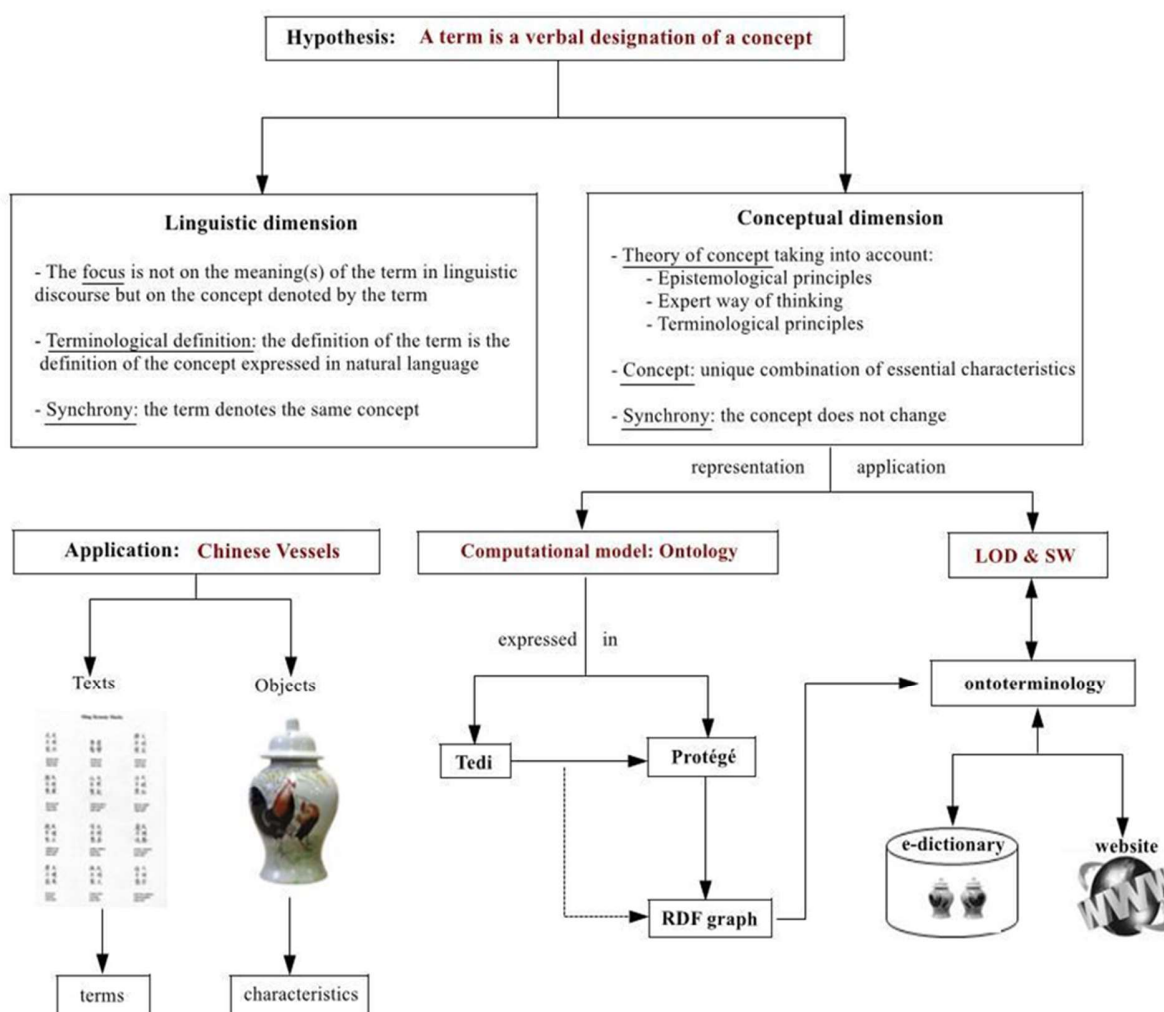


Figure 1.1. The research topics map.

The first stage of our work was to select the set of vases to study and to identify the terms denoting them. The set of objects had to be representative of the richness of the domain without being too big since the main goal was to define the ontology rather than populating it. One hundred forty-nine objects, representing about forty different types of vases, were selected from different museums in China. The museum collections included those of the Palace Museum, which owns the most important collection of Chinese ceramics, the National Museum of China, and the Guangdong Museum.

The selection of objects was based on the following criteria: a/ the collection of ceramics had to be recognized as a reference in ceramic vessels in China, b/ information about the collection should be publicly available and precise enough for the building of an ontology, and c/ the objects had to be as different as possible in terms of their shapes, manufacturing techniques, decoration, etc. The terms designating the object are known to and used by the experts. They are extracted from the description of collections, specific glossaries, and museums websites.

The notion of concept is at the core of the thesis. But which notion of concept? Its definition depends on whether one is a linguist, a terminologist, a knowledge engineer, or a domain expert, only to mention those that concern our work. Although the final result must be in a computational form, we decided not to follow the knowledge engineering point of view, which would force experts to change their way of thinking. We adopted the approach of experts in conceptualization, postponing the issue of translating this conceptualization into a computational form.

A concept is thus defined as a unique combination of essential characteristics. Concepts are organised into a conceptual system linked by different relationships. The subsumption relationship (generic/specific) allows to define concepts according to the Aristotelian definition of species (specific concept) in genus (generic concept) and differentia (essential and specific characteristic). Other relationships, such as part-of and associative relations, complete the network of concepts. This approach is compliant with the ISO principles on Terminology (ISO 1087 and ISO 704), which are designed for human communication, not software systems. Since the Aristotelian definition is applicable both to the linguistic and conceptual dimensions, it will be also used for generating the definition of terms in natural language from the formal definition of concepts.

Such a definition of concept raises two issues. The first one is identifying the essential characteristics which compose the concept. Let us recall that an essential characteristic is a characteristic which, if removed from the object, the object is no more what it is. The second issue is about combining essential characteristics. Indeed, if any set of essential and compatible characteristics potentially defines a concept from a formal point of view, not all of them are meaningful for experts.

There are two approaches for identifying essential characteristics. The first one relies on comparing objects between them. Identifying differences between objects is a useful means towards identifying essential characteristics. The differences can be functional (e.g., vase for decoration, for storing, etc.), material (in clay, in bronze, in gold), structural (with or without foot, with pierced-handles, etc.). The presence or the absence of a component can be interpreted as an essential characteristic. For example, a Chinese ceramic vase can have or not a lid, a neck, handles, etc.

The second approach for identifying essential characteristics is based on a morphological analysis of Chinese terms. Chinese characters directly express knowledge about the denoted objects. For example, the last character of the term “清雍正粉青釉凸花如意耳蒜头瓷瓶” indicates the type of vessel (“瓶” vase) and the others, called modifiers, express knowledge of different nature, either essential, such as material (“瓷” porcelain), shape (“蒜头” garlic-like head), type of handles (“如意耳” Ru-Yi handle), or descriptive characteristics, such as decoration (“凸花” designed with flowers) and glaze and colour (“粉青釉” powder blue glaze). The first characters precise the dynasty (“清” Qing dynasty) and emperor (“雍正” Yongzheng).

The next stage consists in combining essential characteristics into sets corresponding to concepts, knowing that not all combinations are meaningful from the domain point of view. Furthermore, the problem of handling the combinatorial explosion of essential characteristics has to be tackled (e.g. 10 pairs of essential characteristics can be deployed in a concept tree of 1024 leaf concepts). It is the reason why we have followed a term-guided approach based on the main idea that a concept is a set of essential characteristics, which is enough stable to be named in a given natural language. For example, the Chinese term “蒜头瓶”,

“garlic vase” in English, denotes the following set of essential characteristics {/vase/, /one mouth/, /garlic shape mouth/, /ring foot/}. Of course, concepts without any designation in natural language can be introduced in order to better structure the conceptual system, e.g. the concept <Vase with one mouth>. Let us note that our approach does not mix terms and concepts names: they belong to different semiotic systems. If terms are given (texts, glossaries, websites, etc.), concept names are built in such way that by reading them we understand the nature of the objects which fall under the concepts: <OneMouthVase without lid with long neck without ring with pierced handles>, where <OneMouthVase> is the generic concept and /without lid/, /with long neck/, /without ring/, /with pierced handles/ the essential characteristics.

The result is a dedicated methodology, which takes some tasks from existing methods and adds what is specific to a “term-and-characteristic” oriented approach for building ontologies, which let us recall it, takes into account the ISO principles on Terminology as well as the way of thinking of experts. This methodology is made up of seven steps (see Figure 4.1): 1) Defining scope and objectives; 2) Identifying terms and objects; 3) Identifying essential characteristics; 4) term-guided concept building; 5) Implementing; 6) Integration; 7) Evaluation.

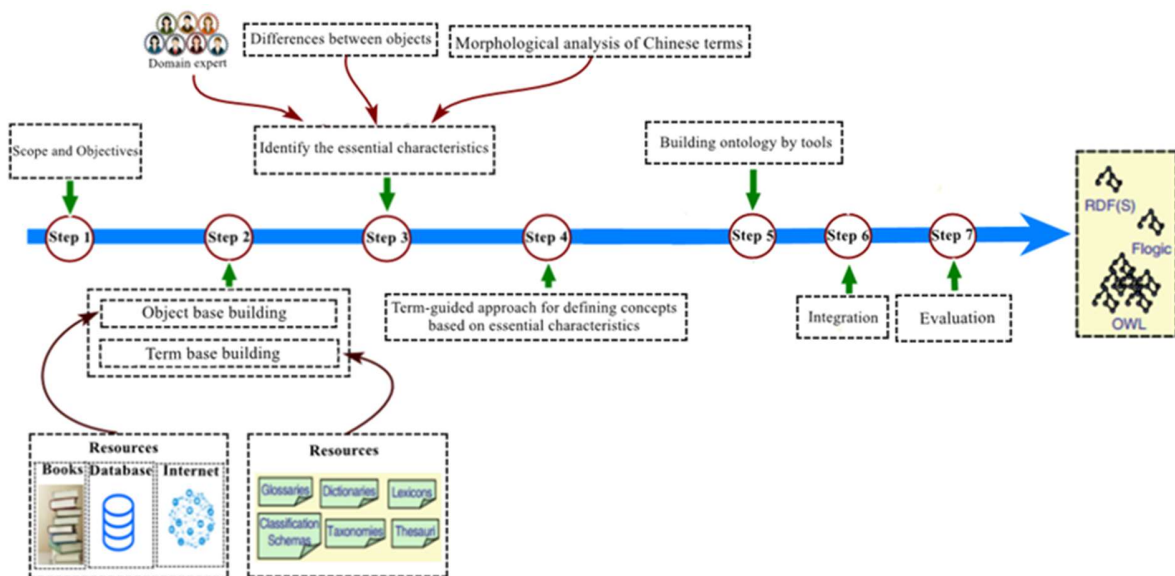


Figure 4.1. The workflow of term-and-characteristic guided methodology.

The implementation was carried out using Protégé. Protégé is the most well-known environment providing a lot of useful functionalities such as graphic user interfaces and reasoners for ontology validation. It is free and supported by a large community. Furthermore, it relies on the W3C standards for the representation of ontologies. Nevertheless, Protégé raises some problems for building ontologies based on essential characteristics. Protégé relies on individuals, and on the main idea that classes are not defined according to their “nature”, but according to the relationships their members have with other objects (property restrictions). Essential characteristics, corresponding to rigid predicates, cannot be directly represented into Protégé. They must be translated in one way or another, either as individuals or as classes. We decided to implement essential characteristics as classes in order to facilitate upgrading and extension of the ontology. Nevertheless, it remains unintuitive for domain experts as Horridge et al. (2013) admit it: “as the group that

developed Protégé, the most widely used ontology editor, we are keenly aware of how difficult the users perceive this task [ontology engineering] to be". The implementation of the linguistic dimension was achieved by annotations (metadata in the W3C sense). About the linguistic dimension, terms are reduced to labels on concepts, i.e. that terms cannot exist without concepts, and linguistic information was implemented as annotations mainly based on SKOS (skos:prefLabel, skos:altLabel, skos:definition, etc.). Based on this implementation, we proposed some writing rules for defining terms in natural language from the formal definition of concepts, in compliant with the Aristotelian definition in genus and differentia. At last, ontology has been linked to external resources, mainly CIDOC CRM and AAT Getty Vocabulary. The result is an ontology in open access, the TAO CI ontology in a RDF/OWL format in open access at the web address: <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl>

It remained to assess the TAO CI ontology built in Protégé, both from the domain knowledge and from its implementation. For the domain knowledge, we relied on competency questions and on domain resources: glossaries, museum web sites, technical descriptions, etc. For the evaluation of the implementation, we used two online platforms. The TAO CI ontology was submitted to OOPS!, an online tool to detect some of the most common pitfalls appearing when developing ontologies, and to OntoMetrics, an online platform to calculate more advanced ontology metrics. We noticed that some results strongly depend on the implementation choices such as the representation of essential characteristics as classes. Nevertheless, in regard to our objectives of classification and terminology, the TAO CI ontology well covers the domain in the sense that each individual clearly falls into a concept (classification), and each concept is clearly defined as a unique combination of essential characteristics (terminology).

The last task was to produce an e-Dictionary available on the web based on the TAO CI ontology as input. Terminography, i.e. building term dictionaries, is different from lexicography, i.e. building word dictionaries. This is the reason why we have not used environments such as Lexonomy, a web platform for writing and publishing word dictionaries on the web. The TAO CI e-Dictionary was implemented in Javascript and gives access to all information related to the linguistic and conceptual dimensions.

At last, a web site dedicated to the TAO CI project has been developed giving access to all resources of the project including the TAO CI ontology and the e-Dictionary: <http://www.dh.ketrc.com/>

The TAO CI project has fulfilled the thesis objectives. It provides a knowledge representation of Chinese ceramics of the Ming and Qing dynasties as a formal ontology. The TAO CI ontology has been implemented in a W3C format (RDF/OWL), and a bilingual e-Dictionary, in English and Chinese, was built from it. The TAO CI ontology is a contribution to publishing and opening Chinese Cultural Heritage on the web as linked open data. As one of the first ontologies and terminologies of the Chinese ceramics, it can be used with profit for linking and sharing Cultural Heritage objects.

Further work will be carried out in two different, but complementary, directions. The first one will focus on the ontological dimension. We have started to complete the ontology by taking into account other types of ceramics, such as jar, bowl, and plate. We are also interested in methodology, in particular how to take into account dependency between essential characteristics as a guideline for ontology building. To this end, we have used Tedi for building the TAO CI ontology. The first results are encouraging (see Annex 3).

On the same topic, we are also interested in building a core ontology of vessels. As a matter of fact, vases constitute a very important domain of knowledge, not only for themselves, but also for the society which has produced and used them. Decorated vases are illustrations of daily life, historical facts, myths, providing information about dress, tools, artefacts, etc. In parallel with the TAO CI project, the Condillac Research Group and KETRC have carried out the Lekythos project which shares similar goals applied to vases of the Ancient Greek (from -700 BC to -323 BC): <http://o4dh.com/lekythos>. The description of vases, either Chinese or Greek, relies on the same metaphor of the human body for describing their structure (mouth, lip, neck, handles, shoulder, belly, foot, etc.). Their function is also similar: for storing, for transport, for decorating, for ritual, etc.). Of course, some of them are culture specific, e.g. kraters (= Greek vases for mixing wine and water to be consumed during banquets).

The second direction for future works concerns the linguistic dimension. Reducing a term to a label on a concept is not satisfactory, even if additional linguistic information can be provided using annotations such as `rdfs:comment`, `skos:note`, `skos:definition`, or `skos:example`. We are interested in pursuing two different approaches to explicitly represent the linguistic dimension of a terminology. The first one aims to stay in the same environment (Protégé) in order to apply some functionalities of Protégé, including reasoners, to the linguistic dimension. Terms can be explicitly represented as individuals of a dedicated class (let us name it *Term*), the linguistic relationships (*hypernym*, *synonymy*, etc.) as object properties, and other linguistic information as data properties (*part of speech*, *gender*, etc.). An object property (let us call it *designates*) with the *Term* class as domain and the *Concept* class as range will link terms and concepts. The second approach would consist in adding an explicit layer for the linguistic dimension. The OntoLex-Lemon standard (<https://www.w3.org/2019/09/lexicog/>) provides a core vocabulary to represent linguistic information related to an ontology. It is targeted at the representation of dictionaries and any other linguistic resource containing lexicographic data and addresses structures and annotations commonly found in lexicography.

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Annex 1:

Chinese characters

1.1 Introduction

As a primary communication tool used by human beings, language is one of the most important ways for people to realize communication. Language is the primary embodiment of national culture. Each country, nation has one or more languages. F. Saussure considered that oral language and written words were different symbol systems, and the only reason for the existence of written words was to express the language (Bally & Sechehaye, 1966). There are two kinds of writing systems: ideographic and phonetic. Both systems may tend to replace spoken form, but the ideographic system may have a more substantial trend:

The statement that the written word tends to replace the spoken one in our minds is true of both systems of writing, but the tendency is stronger in the ideographic system. To a Chinese, an ideogram and a spoken word are both symbols of an idea; to him, writing is a second language, and if two words that have the same sound are used in conversation, he may resort to writing in order to express his thought. However, in Chinese, the mental substitution of the written word for the spoken word does not have the annoying consequences that it has in a phonetic system, for the substitution is absolute; the same graphic symbol can stand for words from different Chinese dialects. (Bally & Sechehaye, 1966, p. 26)

Saussure's view may apply to the phonetic system, such as English, French. However, for the ideographic system, written words could not reflect the actual meaning of ideographic writing. For example, Chinese character, as an ideographic system, needs to combine phonetic, morphology, and meaning to reflect the linguistic meaning. “Signifier” (significant) and “signified” (signifié) are two aspects put forward by Saussure. They are used to discuss structural features of the symbol system itself and the dependence between symbols and concepts. “Signifier” is used to refer to the “sound pattern” of words as symbols, which could also be understood as the words we usually refer to, and “signified” refers to the concept of the representative things that the words refer to as “signifier” (Bally & Sechehaye, 1966, p. 65). From the terminology perspective, “signifier” could refer to terms and “signified” could refer to concepts. The definition of signifier and signified in Chinese terms should be considered in combination with phonetics, morphology, and meaning. So, it is helpful to comprehend the “signifier” and “signified” of Chinese terms by understanding the phonetics, morphology, and meaning of Chinese characters.

This chapter will introduce the development history of Chinese characters from Pictograph to Mandarin and are phonetics, morphology, and meaning of Chinese characters.

1.2 History of Chinese characters

China is the world's four ancient civilizations with about 5000 years of history and culture, which has about twenty-four dynasties (Figure 1). As a symbol, Chinese characters have been developing for more than 5000 years. The evolution of Chinese characters could be roughly divided into seven stages: original characters (原始文字, *yuán shǐ wén zì*), oracle-bone script (甲骨文, *jiǎ gǔ wén*), bronze script (金文, *jīn wén*), Warring States

characters (战国文字, *zhàn guó wén zì*), seal script (篆书, *zhuàn shū*), a clerical script (隶书, *lì shū*), and regular script (楷书, *kǎi shū*) including semi-cursive script (行书, *xíng shū*) and cursive script (草书, *cǎo shū*).

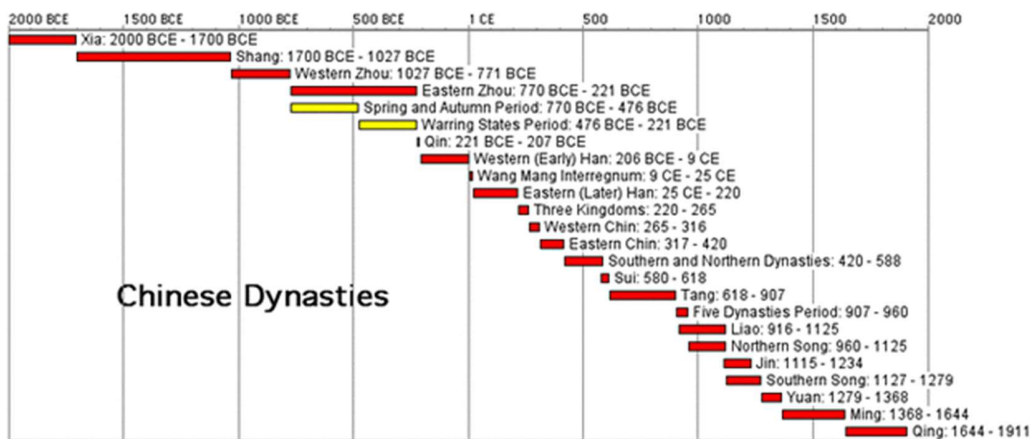


Figure 1. Chinese dynasties (adapted from the internet).

1.2.1 Original characters

Before appearing characters, people invented various ways to record things, such as keeping records by tying knots on the ropes (Figure 2.a). The size of the knot determined the importance of recording things. In another way, to reach a contract, people could carve lines into wooden bars and divide them into two halves, half for each person. This method was to record the contract reached, so it was also called a carved symbol (Figure 2.b). Later, to facilitate communication, people expressed their ideas by drawing symbols according to the shape of the specific thing. Those symbols were engraved on wood, pottery (Figure 2.c), or animal bones (Figure 2.d). We call these symbols and patterns produced by different ways of recording events as original characters, which were concentrated before the Shang dynasty (before 1700BCE) (Figure 1).



Figure 2. Original Characters (adapted from the internet).

1.2.2 Oracle-bone scripts

Oracle-bone script originated in the Shang dynasty (商朝, *shāng cháo*) which was from 1700BCE to 1027 BCE (Figure 1). Oracle-bone scripts are inscriptions on tortoise shells and animal bones, most of which were the contents of divination and sacrifice (Figure 3.a). The oracle-bone script was a sophisticated writing system, which was considered as the first form of Chinese characters. The oracle-bone script was developed from ideographic symbols of original characters, so it belongs to pictograph characters. For example, the oracle-bone script character “人” (person) came from the body posture of ancient people when they met and greeted (Figure 3.b). Figure 3.c shows the oracle-bone script of Chinese zodiacs which include rats (鼠, *shǔ*), cattle (牛, *niú*), tiger (虎, *hǔ*), rabbit (兔, *tù*), dragon (龙, *lóng*), snake (蛇, *shé*), horse (马, *mǎ*), sheep (羊, *yáng*), monkey (猴, *hóu*), chicken (鸡, *jī*), dog (狗, *gǒu*), and pig (猪, *zhū*). By observing the oracle-bone script of Chinese zodiacs, we could find that these oracle-bone scripts originated from animal shapes.

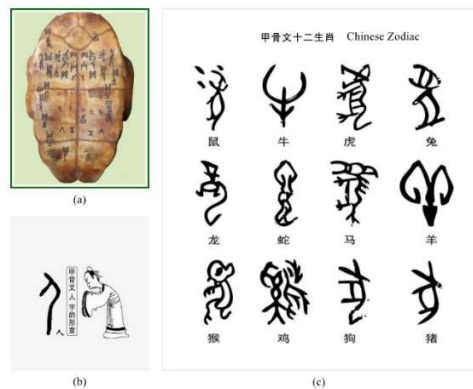


Figure 3. Oracle bone script (adapted from the internet).

1.2.3 Bronze scripts

Because of the popularity of bronze ware, it was used as a carrier of characters. So many characters were engraved on the surface of bronze vessels, which were called bronze script. It often was carved on the ZhongDing (钟鼎 *zhōng dǐng*) and drum-shaped stone blocks (石鼓 *shí gǔ*), so it was also called inscriptions ZhongDing (钟鼎文 *zhōng dǐng wén*) (Figure 4.a) and inscription on drum-shaped stone blocks (石鼓文 *shí gǔ wén*) (Figure 4.b). The bronze script began in the Xia and Shang dynasties and became popular with the Western Zhou dynasty from 1027 BCE to 771 BCE. Bronze scripts were most closely related to oracle bone script, but it's pictographic degree was higher and was simplified. For example, Fig 4.c shows two different characters that are “火” and “山” from oracle bone script to bronze script. Compared with the oracle bone script, bronze scripts are more abstract and close to modern Chinese characters in Figure 4.c.

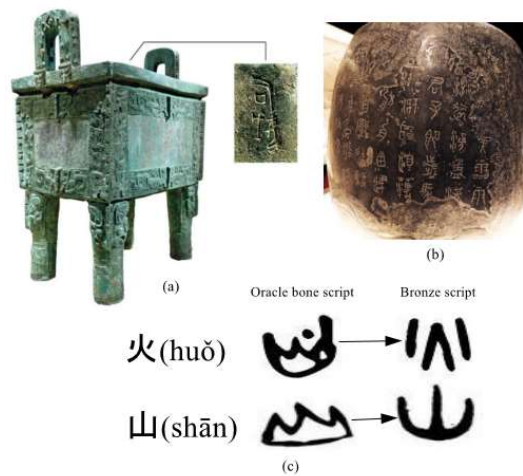


Figure 4. Bronze script (adapted from the internet).

1.2.4 Warring states scripts

Different from the oracle-bone scripts and bronze scripts, the naming of Chinese characters in warring states script was based on a historical period rather than on character carriers. There are many kinds of character carriers in Warring States scripts, such as bamboo slips, silk, bronze, stone carving, and jade (Figure 5). The intention of warring states script not only referred to characters during the Warring States period, but also included ancient characters used by Qi (齐 *qí*), Han (韩 *hán*), Yan (燕 *yān*), Zhao (赵 *zhào*), Wei (魏 *wèi*), Chu (楚 *chǔ*), Qin (秦 *qín*), and other countries from the end of Spring and Autumn period to the unification of Qin (from 770 BCE to 221 BCE) (Figure 1). The distinctive feature of Warring States scripts is profiled and allophone because of the different regions, different material of carriers, different writers, but there are two development trends: simplification and enhancement of pictophonetic trend (Zhiming Hu, 2015, p. 32). In the evolution of Chinese characters, Warring States scripts played the transitional stage between the oracle bone script and seal script of Qin.



Figure 5. Warring states script (adapted from the internet).

1.2.5 Seal scripts

Seal script includes large seal script and small seal script. It is said that the large seal script originated in the late Western Zhou dynasty (1027 BCE – 771 BCE), and its principal feature is lines of characters and standardization of characters. The original irregular graphics of the characters gradually developed into the neat structure of the characters, which laid the foundation of the square characters.

After the Qin dynasty unified the six countries, it used the small seal script to unify the six countries' characters. Compared with the large seal script, the small seal script had almost no traces of the hieroglyphic writing and the strokes of the characters were simple, neat, and arranged in order. The structure and outline of characters became fixed. The small seal script was the first production of standardized Chinese characters in China, which had an important historical position. For example, Figure 6 displays the large seal script and small seal script.



Figure 6. Seal script (adapted from the internet).

1.2.6 Clerical scripts

The Qin dynasty unified six countries' characters with small seal characters, but it was challenging to write and use in practice and not popular among people. So clerical scripts (Figure 7) were produced and matured in the Han dynasty. The clerical script was the boundary between ancient and modern characters and also was the starting point of modern characters. Compared with the seal script, the shape changed from circle to square, forming a Chinese character composed of strokes, such as horizontal (橫, *héng*), vertical (豎, *shù*), dot (點, *diǎn*), apostrophe (撇, *piě*) laying the foundation for a later regular script.



Figure 7. Clerical script (adapted from the internet).

1.2.7 Regular script (cursive script, semi-cursive script)

The regular script, semi-cursive script, and cursive script are popular with modern society. Regular scripts were an improvement of the clerical script, which appeared in the Eastern Han dynasty and matured in the Tang dynasty (Figure 8.a). The Cihai¹³³ interpreted regular script as “形体方正, 笔画平直, 可做楷模, 故名楷书” (Zhengnong Xia, 1999), which meant the regular script could be used as a model and standard. Cursive scripts were a kind of variation caused by scribbling clerical style in drafting manuscripts, which later became a standard writing method and even evolved into a pure calligraphy art (Figure 8.c). Semi-cursive scripts were a kind of writing style to solve the slow writing speed of regular scripts and illegibility of cursive scripts (Figure 8.b). It took simplicity as its goal and had stable writing quality. Currently, we most commonly use the regular script and semi-cursive script.

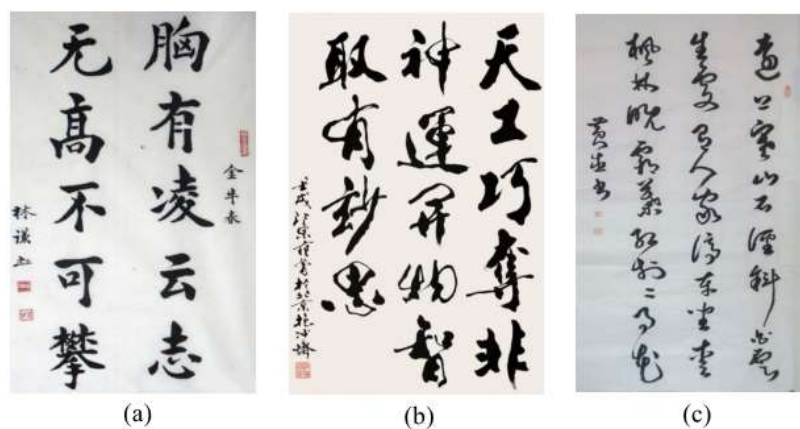


Figure 8. The regular script, semi-cursive script, and cursive script (adapted from the internet).

1.3. Morphology, phonology, and meaning of Chinese characters

Many of Chinese characters have pictographic meaning, so the morphology of Chinese characters have a particular impact on the Chinese character meaning. A Chinese character may have a different pronunciation and construction method, which leads to multiple meanings of Chinese characters. Chinese characters are the ideographic system. So it is helpful to understand the meaning of Chinese characters by combining morphology, phonology, and meaning.

1.3.1 Morphology of Chinese characters

1.3.1.1 Component of Chinese characters

Morphology is a branch of linguistics, which aims to describe and explain the morphological patterns of human languages (Haspelmath & D. Sims, Andrea, 2002, p. 6). There are two different definitions of morphology. One of them is “Morphology is the study of systematic covariation in the form and meaning of words.” (Haspelmath & D. Sims, Andrea, 2002, p. 1). Another one is “Morphology is the study of the combination of morphemes to yield words” (Haspelmath & D. Sims, Andrea, 2002, p. 3). Compared with

¹³³ <https://en.wikipedia.org/wiki/Cihai>

those two definitions, the second one is simpler and to easily comprehend. The work of analyzing morphology is mainly relative to identification constituents of words and word-making.

Chinese characters could be divided into two types: single-component character (独体字) and multiple-component character (合体字). The single-component character could not be subdivided, while the multiple-component character is composed of several components. In English, the word is composed of 26 alphabets. In Chinese, the Chinese character is composed of three factors: strokes (笔画), stroke order (笔顺), side (偏旁).

Strokes refer to the dots and lines of various shapes that make up Chinese characters, which are the smallest unit of Chinese characters. There are eight basic strokes of traditional Chinese characters, namely “dot stroke (点, *diǎn*, 丶), horizontal stroke (横, *héng*, 一), vertical stroke (竖, *shù*, |), left-falling stroke (撇, *piě*, 丿), right-falling stroke (捺, *nà*, ㇇), rising stroke (提, *tí*, ㇇), turning strokes (折, *zhé*, 𠃍), or hook stroke (钩, *gōu*, 丨)”.

Stroke orders are the order of writing. The general rules of stroke orders are first horizontal stroke and then vertical stroke, first left-falling stroke and then right-falling stroke, from top to down, from left to right, from outside to inner, first middle and then two sides, first inside and then sealing.

Sides are part of multiple-component characters. In ancient, the left side of Chinese characters that are left-right structure was called Pian (偏, *piān*), and the right side was called Pang (旁, *páng*). Now all components of Chinese characters are called sides (偏旁, *piān páng*), such as 冫 (两点水, *liǎng diǎn shuǐ*), 讠 (言字旁, *yán zì páng*), 钅 (金字旁, *jīn zì páng*). if the side decides the meaning of characters, this side is also called as bushou (部首 *bù shǒu*). For the Form and Sound character¹³⁴ (形声字 *xíng shēng zì*) in the six categories¹³⁵, Chinese character sides that express the meaning are called "Form sides" (形旁 *xíng páng*), and other sides that express the sound are called "Sound sides" (声旁 *shēng páng*). The Form sides of the Form and Sound character could only indicate the scope of particular meaning or only the category of things, so it could not express the specific meaning of this Form and Sound character. In addition to the Sound system function, the Sound side of Form and Sound characters often has the function of expressing meaning. For example, the Chinese character “把” (handle in English) is composed of “扌” that that is Form sides and “巴” that is Sound sides. The meaning of “扌” is similar to the function of hands used to hold things. So the meaning of “把” is the handle. The pronunciation of “把” is similar to “巴”.

1.3.1.2 Approach for making Chinese character

Xu Shen¹³⁶ first put forward the six categories of construction method of Chinese characters in “说文解字” (*shuō wén jiě zì*). Six categories of Chinese characters include pictographs (象形, *xiàng xíng*), indicators of

¹³⁴ Semantic-phonetic compound characters are a way of making chinese characters.

¹³⁵ Six categories are six categories of Chinese characters in *shuō wén jiě zì* (说文解字) that It is the first Chinese character book that systematically analyzes the Chinese character's form and source, and it is also one of the earliest dictionaries in the world.

¹³⁶ He was a famous philologist, politician and writer in the Eastern Han dynasty from 58 CE to 148 CE.

function (指事, *zhǐ shì*), form and sound (形声, *xíng shēng*), combining meaning (会意, *huì yì*), reciprocally glossing (转注, *zhuǎn zhù*), loaning character (假借, *jiǎ jiè*) (Lewis, 1999).

Pictographs are the lines and strokes of characters to draw out the shape characteristics of the object to be expressed. For example, Figure 9 shows the water, sun, fire, and moon pictograph characters. However, for some things, this method could not draw out and express.

Form and sound belong to the method of making multiple-component characters, which consist of a semantic element and an element indicating pronunciation. For example, handle (把, *bǎ*).

Combining meaning also belongs to the method of making multiple-component characters, which consists of two or more independent characters. So it unites those two or more semantic elements. For example, the Chinese character forest (林, *lín*) is composed of wood (木, *mù*). The meaning of 林 is similar to 木.

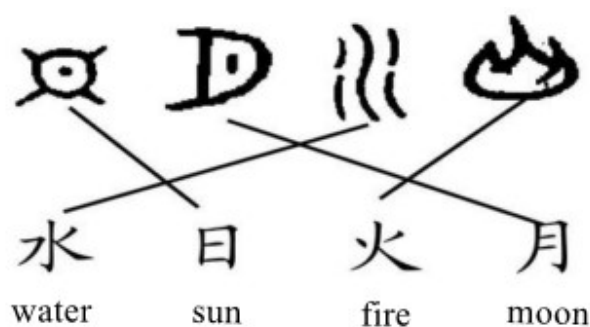


Figure 9. Pictographs Chinese characters.

Indicators of Function, whose forms are iconic without being based on concrete objects, are different from the pictograph¹³⁷. For example, the Chinese character knife (刀, *dāo*) adds a dot to indicate blade (刃, *rèn*).

Reciprocally glossing has different explanations in different experts. In the development process of words, new parts of speech or meaning or pronunciation are evolved. People improve old characters' shapes to recreate new characters, and old and new characters are still linked in sound, morphology, or meaning. For example, both the Chinese character “老” (*lǎo*) and “考” (*kǎo*) have the meaning of being old. The word “lǎo” in the language (referring to “spoken language”) had already created the word “考” to record it. Later, there was a change in the spoken language, and “老” was pronounced as “𠂔” (*kǎo*), so a synonymous “𠂔” (*lǎo*, the current “考” character) was noted on the “𠂔” and written as “考” (a new word “考”)¹³⁸.

Loaning character is that word uses a homonym to represent this word meaning according to its sound in the language, which has no written form of characters. For example, the Chinese character “长” means growth when it pronounces *zhǎng*, while it means long under *cháng* pronunciation. Namely, the long (*cháng*) meaning is put on the growth (*zhǎng*).

¹³⁷ https://en.wikipedia.org/wiki/Xu_Shen

¹³⁸ <https://baike.baidu.com/item/%E5%85%AD%E4%B9%A6/7841?fr=aladdin>

Pictographs, indicators of function, form and sound, and combining meaning are the most critical four approaches of making Chinese characters, most of which are form and sound characters.

1.3.2 Phonology of Chinese characters

Sun said that “Phonetics is the study of the pronunciation of spoken languages” (Sun, 2006, p. 34). In Chinese, there are many dialects, which have different pronunciations, such as Wu, Hui, Min, Yue (William S-Y Wang & Chaofen Sun, 2015, p. 150). These dialects are not the research object of this thesis. The pronunciation of standard Chinese is the mandarin, which is also called the universal language (普通话, *pǔ tōng huà*). Mandarin is the official language and popular in China. This chapter will present the phonemic system of mandarin, which is Pinyin (拼音) used to annotate mandarin sounds. For example, the Chinese characters “水”, whose Pinyin is “*shuǐ*”, is water in English.

1.3.2.1 Chinese character phonology-Pinyin

Pinyin adapts the 26 Latin alphabets, whose pronunciations are different from western languages. A syllable of Chinese is composed of an initial segmental consonant, a medial (also known as on-glide), a vowel, a syllabic terminal (or off-glide), and a supra-segmental tone (Sun, 2006, p. 34). The analysis of Chinese Pinyin focuses on three aspects: initials, finals, and tones. Initials are consonants that are used in front of a vowel and form a complete syllable with the vowel. The Pinyin includes 23 initials that are b, p, m, f, d, t, n, l, g, k, h, j, q, x, zh, ch, sh, r, z, c, s, y, w. The vowel is the part of a Chinese character Pinyin except for the initial and tone. The vowel has 39, such as a, o, e, ie, ia, ua, uo, üe, üan. The mandarin has four basic tones, which are the first tone, second tone, third tone, and fourth tone (Figure 10).

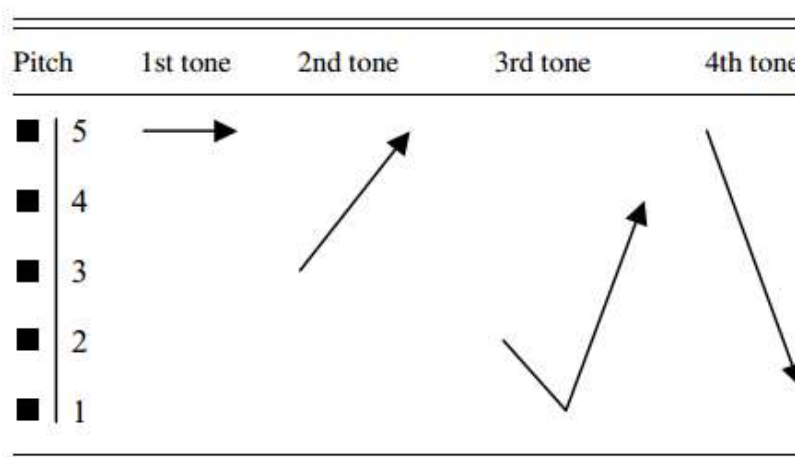


Figure 10. The four basic tones.

The first tone is at the same five-pitch from start to end, which is also called the high-level tone. The first tone’s writing style is “-”, such as *āi, zhōng*. The second starts at three-pitch and ends at five-pitch, whose writing style is “ˊ”, such as *xué, bó*. The third tone is beginning at level 2 pitch and reducing to level 1 pitch, then rising to level 3 pitch. The third tone writing style is “ˇ”, such as *yǔ, chǔ*. The fourth tone starts at level

5 pitch and then drops to level 1, which writing style is “ˊ”, such as *dà, xiàn*. There is a neutral tone, which does not have any writing style and used at some grammatical items such as a verbal suffix like *le, a*.

There is an example to analyze the Pinyin. For example, the Chinese character “水” is water in English, which Pinyin is “*shuǐ*”. In *shuǐ*, the initial is the “*sh*”, and the finals are “*ui*”, and the tone is the third tone.

1.3.3 Chinese character meaning

Chinese characters are ideographs. A Chinese character represents a word or a morpheme in Chinese, which makes the features of the unifying of phonology, morphology, and meaning. The following will present the relationship between the meaning, morphology, and phonetics of Chinese characters.

Meaning and morphology. In a sense, the morphology of Chinese characters determined the meaning of Chinese characters. For example, to express things related to wood (木), Chinese characters “树” (tree), “林” (grove), “森” (forest) all use “木” as the radical. The meaning of “木” is a hard substance that forms the branches and trunks of trees and can be used as a building material, for making things, or as a fuel¹³⁹. The meaning of the tree is “a tall plant that has a wooden trunk and branches that grow from its upper part”. The grove meaning is “a group of trees planted close together”.¹⁴⁰ The meaning of the forest is “a large area of land covered with trees and plants, usually larger than wood, or the trees and plants themselves”¹⁴¹. Through analyzing the meanings of trees, groves, and forests, we could find that they are related to wood meaning. The same example is “江” (Yangtze), “河” (river), “湖” (lake), “海” (sea) uses “氵” as the radical, which is related to water. So, the Chinese character meaning relates to morphology and needs to consider the morphology meaning.

Phonology and meaning. In six categories, there is a way of making characters by loaning character, that is, using an existing character to represent the new meaning of spoken language, which also causes a Chinese character to have multiple pronunciation and meaning. For example, the Chinese character “长” has two pronunciations “*cháng*” and “*zhǎng*”. When the “长” pronounces “*cháng*,” it means long. When the “长” pronounces “*zhǎng*”, it means growth, leader, or increase. So, considering the meanings of characters need to combine the phonology of characters.

From a linguistic perspective, studying Chinese characters need to combine morphology, phonology, and meaning. Furthermore, the study of Chinese terminology also requires a combination of morphology, phonology, and meaning because the Chinese terminology is composed of Chinese characters.

¹³⁹ <https://dictionary.cambridge.org/dictionary/english-chinese-simplified/wood>

¹⁴⁰ <https://dictionary.cambridge.org/dictionary/english-chinese-simplified/grove>

¹⁴¹ <https://dictionary.cambridge.org/dictionary/english-chinese-simplified/forest>

Annex 2

TAO CI Vocabulary (Ontology)

Title:	TAO CI ontology vocabularies
Publisher:	Condillac research group, LISTIC Lab, University Savoie Mont-Blanc KETRC, Liaocheng University
Creators:	Tong WEI
Latest version:	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl
Prefix:	otc: < < >
Date:	2020-08-20
Description:	The TAO CI (“ceramic” in English) ontology focuses on the Chinese Ceramic of the Ming and Qing dynasties. It aims to provide a model (ontology) to open, publish, and link data of Chinese ceramics onto the Semantic Web for Chinese museums and anyone interested in it.

Term Name: Component	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Label	Component
Type of Term	Class
Comment	A part that combines with other parts to form something bigger.
Term Name: Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Label	Belly
Type of Term	Class
Comment	It is used to indicate the part of the vase between shoulder and bottom.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: Bulge Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#BulgeBelly
Label	Bulge Belly
Type of Term	Class
Disjoint with	otc:DrizzlingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Cylindrical Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#CylindricalBelly
Label	Cylindrical Belly
Type of Term	Class
Disjoint with	otc:DrizzlingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Deep Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#DeepBelly

Label	Deep Belly
Type of Term	Class
Disjoint with	otc:ShallowBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Drooping Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#DroopingBelly
Label	Drooping Belly
Type of Term	Class
Disjoint with	otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Flat Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FlatBelly
Label	Flat Belly
Type of Term	Class
Disjoint with	otc:DroopingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Globular Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#GlobularBelly
Label	Globular Belly
Type of Term	Class
Disjoint with	otc:DroopingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Gourd Shaped Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#GourdShapedBelly
Label	Gourd Shaped Belly
Type of Term	Class
Disjoint with	otc:DroopingBelly, otc:MultiprismBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Multiprism Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#MultiprismBelly
Label	Multiprism Belly
Type of Term	Class
Disjoint with	otc:DroopingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Oblate Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OblateBelly
Label	Oblate Belly
Type of Term	Class

Disjoint with	otc:DroopingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Pear Shaped Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PearShapedBelly
Label	Pear Shaped Belly
Type of Term	Class
Disjoint with	otc:DroopingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Round Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#RoundBelly
Label	Round Belly
Type of Term	Class
Disjoint with	otc:DroopingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Shallow Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ShallowBelly
Label	Shallow Belly
Type of Term	Class
Disjoint with	otc:DeepBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Spheroid Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SpheroidBelly
Label	Spheroid Belly
Type of Term	Class
Disjoint with	otc:DroopingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Square Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SquareBelly
Label	Square Belly
Type of Term	Class
Disjoint with	otc:DroopingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:SwellingBodyTaperingDownward, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Swelling Body Tapering Downward	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SwellingBodyTaperingDownward
Label	Swelling Body Tapering Downward
Type of Term	Class

Disjoint with	otc:DropingBelly, otc:MultiprismBelly, otc:GourdShapedBelly, otc:FlatBelly, otc:PearShapedBelly, otc:CylindricalBelly, otc:GlobularBelly, otc:Multi-prismBelly, otc:OblateBelly, otc:SquareBelly, otc:SpheroidBelly, otc:RoundBelly, otc:BulgeBelly
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Belly
Term Name: Bottom	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Bottom
Label	Bottom
Type of Term	Class
Comment	The lowest part of vases
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: Flat Bottom	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FlatBottom
Label	Flat Bottom
Type of Term	Class
Comment	The lowest part of the vase is flat.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Bottom
Term Name: Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Foot
Label	Foot
Type of Term	Class
Comment	The part of vases for supporting vases.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: Concave Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ConcaveFoot
Label	Concave Foot
Type of Term	Class
Comment	It is used to indicate the foot that is not obvious in the bottom.
Disjoint with	otc:SquareFoot, otc:RingFoot
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Foot
Term Name: Convergence Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ConvergenceFoot
Label	Convergence Foot
Type of Term	Class
Disjoint with	otc:Outward, otc:StraightFoot
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Foot
Term Name: High Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#HighFoot
Label	High Foot
Type of Term	Class
Disjoint with	Otc:LowFoot
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Foot
Term Name: Low Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#HighFoot
Label	High Foot
Type of Term	Class
Disjoint with	otc:LowFoot
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Foot
Term Name: Outward Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OutwardFoot
Label	Outward Foot
Type of Term	Class

Disjoint with	otc:ConvergenceFoot, otc:StraightFoot
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Foot
Term Name: Ring Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#RingFoot
Label	Ring Foot
Type of Term	Class
Disjoint with	otc:ConcaveFoot, otc:SquareFoot
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Foot
Term Name: Square Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SquareFoot
Label	Square Foot
Type of Term	Class
Disjoint with	otc:ConcaveFoot, otc:RingFoot
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Foot
Term Name: Straight Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#StraightFoot
Label	Straight Foot
Type of Term	Class
Disjoin with	otc:ConvergenceFoot, otc:OutwardFoot
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Foot
Term Name: Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Label	Handle
Type of Term	Class
Common	a part of an object designed for holding, moving, or carrying the object easily
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: Dragon-massk Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Dragon-masskHandle
Label	Dragon-massk Handle
Type of Term	Class
Common	A handle looks like a dragon-massk.
Disjoint with	otc: DragonShapedHandle, otc: ElephantShapedHandle, otc: FishShapedHandle, otc: HalberdShapedHandle, otc: PhoenixShapedHandle, otc: PiercedHandle, otc: RibbonShapedHandle, otc: Ru-YiShapedHandle
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Term Name: Dragon Shaped Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#DragonShapedHandle
Label	Dragon Shaped Handle
Type of Term	Class
Common	A handle looks like a dragon.
Disjoint with	otc: Dragon-masskHandle, otc: ElephantShapedHandle, otc: FishShapedHandle, otc: HalberdShapedHandle, otc: PhoenixShapedHandle, otc: PiercedHandle, otc: RibbonShapedHandle, otc: Ru-YiShapedHandle
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Term Name: Elephant Shaped Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ElephantShapedHandle
Label	Elephant Shaped Handle
Type of Term	Class
Common	A handle looks like an elephant.

Disjoint with	otc: DragonShapedHandle, otc: FishShapedHandle, otc: Dragon-masskHandle, otc: HalberdShapedHandle, otc: PhoenixShapedHandle, otc: PiercedHandle, otc: RibbonShapedHandle, otc: Ru-YiShapedHandle
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Term Name: Fish Shaped Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FishShapedHandle
Label	Fish Shaped Handle
Type of Term	Class
Common	A handle looks like a fish.
Disjoint with	otc: ElephantShapedHandle, otc: DragonShapedHandle, otc: Dragon-masskHandle, otc: HalberdShapedHandle, otc: PhoenixShapedHandle, otc: PiercedHandle, otc: RibbonShapedHandle, otc: Ru-YiShapedHandle
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Term Name: Halberd Shaped Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#HalberdShapedHandle
Label	Halberd Shaped Handle
Type of Term	Class
Common	A handle looks like a halberd.
Disjoint with	otc: ElephantShapedHandle, otc: DragonShapedHandle, otc: FishShapedHandle, otc: Dragon-masskHandle, otc: HalberdShapedHandle, otc: PhoenixShapedHandle, otc: PiercedHandle, otc: RibbonShapedHandle, otc: Ru-YiShapedHandle
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Term Name: Phoenix Shaped Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PhoenixShapedHandle
Label	Phoenix Shaped Handle
Type of Term	Class
Common	A handle looks like a phoenix.
Disjoint with	otc: ElephantShapedHandle, otc: DragonShapedHandle, otc: FishShapedHandle, otc: Dragon-masskHandle, otc: HalberdShapedHandle, otc: PiercedHandle, otc: RibbonShapedHandle, otc: Ru-YiShapedHandle
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Term Name: Pierced Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PiercedHandle
Label	Pierced Handle
Type of Term	Class
Common	A handle looks like a piercing.
Disjoint with	otc: ElephantShapedHandle, otc: DragonShapedHandle, otc: FishShapedHandle, otc: Dragon-masskHandle, otc: HalberdShapedHandle, otc: PhoenixShapedHandle, otc: RibbonShapedHandle, otc: Ru-YiShapedHandle
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Term Name: Ribbon Shaped Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#RibbonShapedHandle
Label	Ribbon Shaped Handle
Type of Term	Class
Common	A handle looks like a ribbon.
Disjoint with	otc: ElephantShapedHandle, otc: DragonShapedHandle, otc: FishShapedHandle, otc: Dragon-masskHandle, otc: HalberdShapedHandle, otc: PhoenixShapedHandle, otc: PiercedHandle, otc: Ru-YiShapedHandle
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Term Name: Ru-Yi Shaped Handle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Ru-YiShapedHandle
Label	Ru-Yi Shaped Handle

Type of Term	Class
Common	A handle looks like a Ru-Yi.
Disjoint with	otc: RibbonShapedHandle, otc: PiercedHandle, otc: PhoenixShapedHandle, otc: HalberdShapedHandle, otc: FishShapedHandle, otc: ElephantShapedHandle, otc: DragonShapedHandle, otc: Dragon-masskHandle, otc: PhoenixShapedHandle,
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Term Name: Lid	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#DragonShapedHandle
Label	Dragon Shaped Handle
Type of Term	Class
Common	It is used to cover the vessel.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Label	Mouth
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: One Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouth
Label	One Mouth
Type of Term	Class
Disjoint with	otc:MultiMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Multi Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#MultiMouth
Label	MultiMouth
Type of Term	Class
Disjoint with	otc:OneMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Brush Washer Shape Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#BrushWasherShapeMouth
Label	Bush Washer Shape Mouth
Type of Term	Class
Disjoint with	otc: TrumpetShapedMouth, otc: PlateShapedMouth, otc: FlowerShapedMouth, otc:GarlicShapedMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Circle Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#CircleMouth
Label	Circle Mouth
Type of Term	Class
Disjoint with	otc:SquareMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Convergence Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ConvergenceMouth
Label	Convergence Mouth
Type of Term	Class
Disjoint with	otc:OutwardMouth, otc:StraightMouth, otc:OpenMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Everted Rim Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#EvertedRimMouth
Label	Everted Rim Mouth

Type of Term	Class
Disjoint with	otc:LipMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Flower Shaped Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FlowerShapedMouth
Label	Flower Shaped Mouth
Type of Term	Class
Disjoint with	otc: TrumpetShapedMouth, otc: PlateShapedMouth, otc:GarlicShapedMouth, otc: BrushWasherShapeMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Garlic Shaped Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#GarlicShapedMouth
Label	Garlic Shaped Mouth
Type of Term	Class
Disjoint with	otc: TrumpetShapedMouth, otc: PlateShapedMouth, otc: FlowerShapedMouth, otc: BrushWasherShapeMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Large Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#LargeMouth
Label	Large Mouth
Type of Term	Class
Disjoint with	otc:SmallMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Lip Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#LipMouth
Label	Lip Mouth
Type of Term	Class
Disjoint with	otc: EvertedRimMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Open Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OpenMouth
Label	Open Mouth
Type of Term	Class
Disjoint with	otc: ConvergenceMouth, otc:OutwardMouth, otc:StraightMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Outward Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OutwardMouth
Label	Outward Mouth
Type of Term	Class
Disjoint with	otc:OpenMouth, otc: ConvergenceMouth, otc:StraightMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Plate Shaped Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PlateShapedMouth
Label	Plate Shaped Mouth
Type of Term	Class
Disjoint with	otc: TrumpetShapedMouth, otc: FlowerShapedMouth, otc:GarlicShapedMouth, otc: BrushWasherShapeMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Small Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SmallMouth
Label	Small Mouth

Type of Term	Class
Disjoint with	otc:LargeMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Square Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SquareMouth
Label	Square Mouth
Type of Term	Class
Disjoint with	otc:CircleMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Straight Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#StraightMouth
Label	Straight Mouth
Type of Term	Class
Disjoint with	otc:OutwardMouth, otc:OpenMouth, otc:ConvergenceMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Trumpet Shaped Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#TrumpetShapedMouth
Label	Trumpet Shaped Mouth
Type of Term	Class
Disjoint with	otc:FlowerShapedMouth, otc:PlateShapedMouth, otc:GarlicShapedMouth, otc:BrushWasherShapeMouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Mouth
Term Name: Neck	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Neck
Label	Neck
Type of Term	Class
Comment	The part of the vase that joins the head to the shoulders
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: Long Neck	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#LongNeck
Label	Long Neck
Type of Term	Class
Disjoint with	otc:ShortNeck
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Neck
Term Name: Bending Neck	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#BendingNeck
Label	Bending Neck
Type of Term	Class
Disjoint with	otc:StraightNeck
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Neck
Term Name: Short Neck	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ShortNeck
Label	Short Neck
Type of Term	Class
Disjoint with	otc:LongNeck
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Neck
Term Name: Straight Neck	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#StraightNeck
Label	Straight Neck
Type of Term	Class
Disjoint with	otc:BendingNeck

Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Neck
Term Name: Slender Neck	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SlenderNeck
Label	Slender Neck
Type of Term	Class
Disjoint with	otc:WideNeck
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Neck
Term Name: Wide Neck	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#WideNeck
Label	Wide Neck
Type of Term	Class
Disjoint with	otc:SlenderNeck
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Neck
Term Name: Ring	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Ring
Label	Ring
Type of Term	Class
Comment	It is a ring that is often on the handles.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: Shoulder	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Shoulder
Label	Shoulder
Type of Term	Class
Comment	The part of a vase that curves out below its opening
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: Circle Shoulder	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#CircleShoulder
Label	Circle Shoulder
Type of Term	Class
Disjoint with	otc:FoldingShoulder, otc:FlatShoulder, otc:SlantingShoulder
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Shoulder
Term Name: Flat Shoulder	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FlatShoulder
Label	Flat Shoulder
Type of Term	Class
Disjoint with	otc:FoldingShoulder, otc:SlantingShoulder, otc:CircleShoulder
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Shoulder
Term Name: Folding Shoulder	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FoldingShoulder
Label	Folding Shoulder
Type of Term	Class
Disjoint with	otc:FlatShoulder, otc:SlantingShoulder, otc:CircleShoulder
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Shoulder
Term Name: Slanting Shoulder	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SlantingShoulder
Label	Slanting Shoulder
Type of Term	Class
Disjoint with	otc:FoldingShoulder, otc:FlatShoulder, otc:CircleShoulder
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Shoulder
Term Name: Spout	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Spout

Label	Spout
Type of Term	Class
Comment	a tube-shaped opening that allows liquids to be poured out of a container
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: Dynasty	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Dynasty
Label	Dynasty
Type of Term	Class
Comment	It is used to describe the period of vessels made.
Term Name: Emperor	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Emperor
Label	Emperor
Type of Term	Class
Comment	It is used to indicate the emperor when the vessel was made.
Term Name: Function	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Label	Function
Type of Term	Class
Comment	It is used to express the vessel function.
Term Name: Function For Cooking	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForCooking
Label	Function For Cooking
Type of Term	Class
Disjoint with	otc: FunctionForDecoration, otc: FunctionForDrawingWater, otc: FunctionForDrinking, otc: FunctionForEating, otc: FunctionForSacrifice, otc: FunctionForSnuff, otc: FunctionForStoringLiquid, otc: FunctionForStoringSolid, otc: FunctionForStoringWashing
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Term Name: Function For Decoration	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForDecoration
Label	Function For Decoration
Type of Term	Class
Disjoint with	otc: FunctionForCooking, otc: FunctionForDrawingWater, otc: FunctionForDrinking, otc: FunctionForEating, otc: FunctionForSacrifice, otc: FunctionForSnuff, otc: FunctionForStoringLiquid, otc: FunctionForStoringSolid, otc: FunctionForStoringWashing
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Term Name: Function For Drawing Water	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForDrawingWater
Label	Function For Drawing Water
Type of Term	Class
Disjoint with	otc: FunctionForCooking, otc: FunctionForDecoration, otc: FunctionForDrinking, otc: FunctionForEating, otc: FunctionForSacrifice, otc: FunctionForSnuff, otc: FunctionForStoringLiquid, otc: FunctionForStoringSolid, otc: FunctionForStoringWashing
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Term Name: Function For Drinking	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForDrinking
Label	Function For Drinking
Type of Term	Class
Disjoint with	otc: FunctionForCooking, otc: FunctionForDecoration, otc: FunctionForDrawingWater, otc: FunctionForEating, otc: FunctionForSacrifice, otc: FunctionForSnuff, otc: FunctionForStoringLiquid, otc: FunctionForStoringSolid, otc: FunctionForStoringWashing
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function

Term Name: Function For Eating	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForEating
Label	Function For Eating
Type of Term	Class
Disjoint with	otc: FunctionForCooking, otc: FunctionForDecoration, otc: FunctionForDrawingWater, otc: FunctionForDrinking, otc: FunctionForSacrifice, otc: FunctionForSnuff, otc: FunctionForStoringLiquid, otc: FunctionForStoringSolid, otc: FunctionForStoringWashing
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Term Name: Function For Sacrifice	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForSacrifice
Label	Function For Sacrifice
Type of Term	Class
Disjoint with	otc: FunctionForCooking, otc: FunctionForDecoration, otc: FunctionForDrawingWater, otc: FunctionForDrinking, otc: FunctionForEating, otc: FunctionForSnuff, otc: FunctionForStoringLiquid, otc: FunctionForStoringSolid, otc: FunctionForStoringWashing
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Term Name: Function For Snuff	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForSnuff
Label	Function For Snuff
Type of Term	Class
Disjoint with	otc: FunctionForCooking, otc: FunctionForDecoration, otc: FunctionForDrawingWater, otc: FunctionForDrinking, otc: FunctionForEating, otc: FunctionForSacrifice, otc: FunctionForStoringLiquid, otc: FunctionForStoringSolid, otc: FunctionForStoringWashing
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Term Name: Function For Storing Liquid	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForStoringLiquid
Label	Function For Storing Liquid
Type of Term	Class
Disjoint with	otc: FunctionForCooking, otc: FunctionForDecoration, otc: FunctionForDrawingWater, otc: FunctionForDrinking, otc: FunctionForEating, otc: FunctionForSacrifice, otc: FunctionForSnuff, otc: FunctionForStoringSolid, otc: FunctionForStoringWashing
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Term Name: Function For Storing Solid	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForStoringSolid
Label	Function For Storing Solid
Type of Term	Class
Disjoint with	otc: FunctionForCooking, otc: FunctionForDecoration, otc: FunctionForDrawingWater, otc: FunctionForDrinking, otc: FunctionForEating, otc: FunctionForSacrifice, otc: FunctionForSnuff, otc: FunctionForStoringLiquid, otc: FunctionForStoringWashing
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Term Name: Function For Washing	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#FunctionForStoringWashing
Label	Function For Storing Liquid
Type of Term	Class
Disjoint with	otc: FunctionForCooking, otc: FunctionForDecoration, otc: FunctionForDrawingWater, otc: FunctionForDrinking, otc: FunctionForEating, otc: FunctionForSacrifice, otc: FunctionForSnuff, otc: FunctionForStoringLiquid, otc: FunctionForStoringSolid
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Term Name: Glaze-Color	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Glaze-Color
Label	Glaze-Color
Type of Term	Class

Term Name: Material	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Material
Label	Material
Type of Term	Class
Common	A physical substance that things can be made from
Term Name: Bronze	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Bronze
Label	Bronze
Type of Term	Class
Disjoint with	otc: Clay, otc: Glass, otc: Gold, otc: Jade, otc: Silver, otc: Wood
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Material
Term Name: Clay	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Clay
Label	Clay
Type of Term	Class
Disjoint with	otc:Bronze, otc: Glass, otc: Gold, otc: Jade, otc: Silver, otc: Wood
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Material
Term Name: Glass	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Glass
Label	Glass
Type of Term	Class
Disjoint with	otc:Bronze, otc: Clay, otc: Gold, otc: Jade, otc: Silver, otc: Wood
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Material
Term Name: Gold	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Gold
Label	Gold
Type of Term	Class
Disjoint with	otc:Bronze, otc: Clay, otc: Glass, otc: Jade, otc: Silver, otc: Wood
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Material
Term Name: Jade	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Jade
Label	Jade
Type of Term	Class
Disjoint with	otc:Bronze, otc: Clay, otc: Glass, otc: Gold, otc: Silver, otc: Wood
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Material
Term Name: Silver	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Silver
Label	Silver
Type of Term	Class
Disjoint with	otc:Bronze, otc: Clay, otc: Glass, otc: Gold, otc: Jade, otc: Wood
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Material
Term Name: Wood	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Wood
Label	Wood
Type of Term	Class
Disjoint with	otc:Bronze, otc: Clay, otc: Glass, otc: Gold, otc: Jade, otc: Silver
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Material
Term Name: ShapeOfBody	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ShapeOfBody
Label	Shape Of Body
Type of Term	Class

Comment	It is about the shape the vessel. The characteristic is mainly used to distinguish vase and Gu.
Term Name: TrumpetShapedBody	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#TrumpetShapedBody
Label	Trumpet Shaped Body
Type of Term	Class
Comment	It is used to indicate the vessel shape that looks like a trumpet.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ShapeOfBody
Term Name: Temperature	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Temperature
Label	Temperature
Type of Term	Class
Comment	It is the temperature that the ceramic is fired for hardening.
Term Name: High Temperature	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#HighTemperature
Label	High Temperature
Type of Term	Class
Disjoint with	otc:LowTemperature
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Temperature
Term Name: Low Temperature	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#LowTemperature
Label	Low Temperature
Type of Term	Class
Disjoint with	otc:LowTemperature
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Temperature
Term Name: Vessel	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Label	Vessel
Type of Term	Class
Term Name: Bronze Vessel	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#BronzeVessel
Label	Bronze Vessel
Type of Term	Class
Disjoint with	otc: ClayVessel, otc: GlassVessel, otc: GoldVessel, otc: JadeVessel, otc: SilverVessel, otc: WoodVessel
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: Clay Vessel	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Label	Clay Vessel
Type of Term	Class
Disjoint with	otc: BronzeVessel, otc: GlassVessel, otc: GoldVessel, otc: JadeVessel, otc: SilverVessel, otc: WoodVessel
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: Glass Vessel	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#GlassVessel
Label	Glass Vessel
Type of Term	Class
Disjoint with	otc: BronzeVessel, otc: ClayVessel, otc: GoldVessel, otc: JadeVessel, otc: SilverVessel, otc: WoodVessel
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: Gold Vessel	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#GoldVessel

Label	Gold Vessel
Type of Term	Class
Disjoint with	otc: BronzeVessel, otc: ClayVessel, otc: GlassVessel, otc: JadeVessel, otc: SilverVessel, otc: WoodVessel
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: Jade Vessel	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#JadeVessel
Label	Jade Vessel
Type of Term	Class
Disjoint with	otc: BronzeVessel, otc: ClayVessel, otc: GlassVessel, otc: GoldVessel, otc: SilverVessel, otc: WoodVessel
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: Silver Vessel	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SilverVessel
Label	Silver Vessel
Type of Term	Class
Disjoint with	otc: BronzeVessel, otc: ClayVessel, otc: GlassVessel, otc: GoldVessel, otc: JadeVessel, otc: WoodVessel
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: Wood Vessel	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#WoodVessel
Label	Wood Vessel
Type of Term	Class
Disjoint with	otc: BronzeVessel, otc: ClayVessel, otc: GlassVessel, otc: GoldVessel, otc: JadeVessel, otc: SilverVessel
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: Basin	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Basin
Label	Basin
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Bo	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Bo
Label	Bo
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Bowl	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Bowl
Label	Bowl
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Box	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Box
Label	Box
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Censer	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Censer
Label	Censer
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel

Term Name: Cup	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Cup
Label	Cup
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Dish	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Dish
Label	Dish
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Gu	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Gu
Label	Gu
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Jar	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Jar
Label	Jar
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Jue	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Jue
Label	Jue
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Jug	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Jug
Label	Jug
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Snuff Bottle	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SnuffBottle
Label	Cup
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Cup
Label	Cup
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Zun	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Zun
Label	Zun
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: Multi Mouth Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#MultiMouthVase
Label	Multi Mouth Vase
Type of Term	Class
Definition	Vase with Multi-mouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vase

Term Name: One Mouth Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Label	One Mouth Vase
Type of Term	Class
Definition	Vase with one mouth
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vase
Term Name: Double-tube Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Double-tubeVase
Label	Double-tube Vase
Definition	Vase with multi-mouth and bending neck
Type of Term	Class
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#MultiMouthVase
Term Name: Twin Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#TwinVase
Label	Twin Vase
Type of Term	Class
Definition	Vase is with lid, multi-mouth of brush washer shape mouth, slanting shoulder, and ring foot
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#MultiMouthVase
Term Name: Arrow Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase
Label	Arrow Vase
Type of Term	Class
Definition	Vase with long neck and pierced handles.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Arrow Vase I	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase_I
Label	Arrow Vase I
Type of Term	Class
Definition	Arrow vase with a square mouth, slanting shoulder, bulge belly, and square foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase
Term Name: Arrow Vase II	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase_II
Label	Arrow Vase II
Type of Term	Class
Definition	Arrow vase with a straight mouth, slanting shoulder, bulge belly, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase
Term Name: Arrow Vase III	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase_III
Label	Arrow Vase III
Type of Term	Class
Definition	Arrow vase with a straight mouth, folding shoulder, swelling body tapering downward, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ArrowVase
Term Name: Awl-handle Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Awl-handleVase
Label	Awl-handle Vase
Type of Term	Class
Definition	Vase with a small mouth, slender and long neck, slanting shoulder, globular belly, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Cong-shaped Vase	

URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Cong-shapedVase
Label	Cong-shaped Vase
Type of Term	Class
Definition	Vase with a small mouth, short neck, flat shoulder, square belly, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Double-gourd Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Double-gourdVase
Label	Double-gourd Vase
Type of Term	Class
Definition	Vase with a small mouth and a gourd-shaped belly.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Double-gourd Vase I	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Double-gourdVase_I
Label	Double-gourd Vase I
Type of Term	Class
Definition	Double-gourd vase with a ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Double-gourdVase
Term Name: Double-gourd Vase II	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Double-gourdVase_II
Label	Double-gourd Vase II
Type of Term	Class
Definition	Double-gourd vase with handles and a square foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Double-gourdVase
Term Name: Double-gourd Vase III	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Double-gourdVase_III
Label	Double-gourd Vase III
Type of Term	Class
Definition	Double-gourd vase with a lid and a slender neck.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Double-gourdVase
Term Name: Elephant Leg Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ElephantLegVase
Label	Elephant Leg Vase
Type of Term	Class
Definition	Vase with an outward mouth, short neck, cylindrical belly, without foot, and flat bottom.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Flower-mouth Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Flower-mouthVase
Label	Flower-mouth Vase
Type of Term	Class
Definition	Vase with a flower shaped mouth, slender neck, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Flower-mouth Vase I	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Flower-mouthVase_I
Label	Flower-mouth Vase I
Type of Term	Class
Definition	Flower-mouth vase with slanting shoulder and globular belly.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Flower-mouthVase
Term Name: Flower-mouth Vase II	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Flower-mouthVase_II
Label	Flower-mouth Vase II
Type of Term	Class

Definition	Flower-mouth vase with a slender neck, round belly, and outward foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Flower-mouthVase
Term Name: Gall-bladder Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Gall-bladderVase
Label	Gall-bladder Vase
Type of Term	Class
Definition	Vase with a slender and long neck, slanting shoulder, drooping belly, and a ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Gall-bladder Vase I	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Gall-bladderVase_I
Label	Gall-bladder Vase I
Type of Term	Class
Definition	Gall-bladder vase with a small mouth.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Gall-bladderVase
Term Name: Gall-bladder Vase II	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Gall-bladderVase_II
Label	Gall-bladder Vase II
Type of Term	Class
Definition	Gall-bladder vase with a straight mouth.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Gall-bladderVase
Term Name: Garlic-head Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Garlic-headVase
Label	Garlic-head Vase
Type of Term	Class
Definition	Vase with a garlic shaped mouth and a ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Garlic-head Vase I	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Garlic-headVase_I
Label	Garlic-head Vase I
Type of Term	Class
Definition	Garlic-head vase with a short neck, circle shoulder, globular belly, and Ru-Yi shaped handles.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Garlic-headVase
Term Name: Garlic-head Vase II	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Garlic-headVase_II
Label	Garlic-head Vase II
Type of Term	Class
Definition	Garlic-head vase with a slender and long neck, slanting shoulder, and a bulge belly.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Garlic-headVase
Term Name: Lantern Shaped Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#LanternShapedVase
Label	Lantern Shaped Vase
Type of Term	Class
Definition	Vase with an outward mouth, a short neck, slanting shoulder, cylindrical belly, and a ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Long-necked Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Long-neckedVase
Label	Long-necked Vase
Type of Term	Class
Definition	Vase with an outward mouth, long neck, bulge belly, and a ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Loosing Ring Vase	

URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#LoosingRingVase
Label	Loosing Ring Vase
Type of Term	Class
Definition	Vase with a plate shaped mouth, long neck, handles, ring, slanting shoulder, drooping belly, high and outward and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Moon Shaped Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#MoonShapedVase
Label	Moon Shaped Vase
Type of Term	Class
Definition	Vase with a straight mouth, slender neck, Ru-Yi shaped handle, circle shoulder, oblate belly, and a ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Oil-hammer Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Oil-hammerVase
Label	Oil-hammer Vase
Type of Term	Class
Definition	Vase without foot with a small mouth, a slender and long neck, slanting shoulder, globular belly, and a flat bottom.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Olive-shaped Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Olive-shapedVase
Label	Olive-shaped Vase
Type of Term	Class
Definition	Vase with a bulge belly and a ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Olive-shaped Vase I	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Olive-shapedVase_I
Label	Olive-shaped Vase I
Type of Term	Class
Definition	Olive-shaped vase with an outward mouth, slender and long neck, and outward foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Olive-shapedVase
Term Name: Olive-shaped Vase II	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Olive-shapedVase_II
Label	Olive-shaped Vase II
Type of Term	Class
Definition	Olive-shaped vase with a straight mouth, short neck, and slanting shoulder.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Olive-shapedVase
Term Name: Pear Shaped Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PearShapedVase
Label	Pear Shaped Vase
Type of Term	Class
Definition	Vase with an outward mouth, slender neck, slanting shoulder, pear shaped belly, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Plum Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PlumVase
Label	Plum Vase
Type of Term	Class
Definition	Vase with a small mouth, short neck, circle shoulder, swelling body tapering downward, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase

Term Name: Plum Vase I	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PlumVase_I
Label	Plum Vase I
Type of Term	Class
Definition	Plum vase with a lid.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PlumVase
Term Name: Plum Vase II	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PlumVase_II
Label	Plum Vase II
Type of Term	Class
Definition	Vase with a lip mouth and without a lid.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#PlumVase
Term Name: Reward Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#RewardVase
Label	Reward Vase
Type of Term	Class
Definition	Vase with an outward mouth, slender and long neck, globular belly, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Rouleau Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#RouleauVase
Label	Rouleau Vase
Type of Term	Class
Definition	Vase with a plate shape mouth, straight neck, fold shoulder, cylindrical belly, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Square Rouleau Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#SquareRouleauVase
Label	Square Rouleau Vase
Type of Term	Class
Definition	Vase with an outward mouth, short neck, flat shoulder, square belly, and square foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Vault-of-heaven Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vault-of-heavenVase
Label	Vault-of-heaven Vase
Type of Term	Class
Definition	Vase with a straight neck and a globular belly.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Vault-of-heaven Vase I	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vault-of-heavenVase_I
Label	Vault-of-heaven Vase I
Type of Term	Class
Definition	Vault-of-heaven vase without foot with a small and lip mouth, a long neck, and a flat bottom.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vault-of-heavenVase
Term Name: Vault-of-heaven Vase II	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vault-of-heavenVase_II
Label	Vault-of-heaven Vase II
Type of Term	Class
Definition	Vault-of-heaven vase with a straight mouth and concave foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vault-of-heavenVase
Term Name: Water-chestnut Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Water-chestnutVase
Label	Water-chestnut Vase

Type of Term	Class
Definition	Vase with a lip shape mouth, a long and slender neck, slanting shoulder, oblate belly, and a ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: Willow-leaf-shaped Vase	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Willow-leaf-shapedVase
Label	Willow-leaf-shaped Vase
Type of Term	Class
Definition	Vase with an outward mouth, short neck, slanting shoulder, swelling body tapering downwards, and ring foot.
Subclass of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#OneMouthVase
Term Name: belong To	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#belongTo
Label	belong to
Type of Term	Property
Comment	It is the relation between emperor and dynasty, such as, Kangxi belongs to Qing dynasty.
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Dynasty
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Emperor
Term Name: depend On	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#dependOn
Label	depend on
Type of Term	Property
Inverse of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#isDependedOn
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Handle
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Ring
Term Name: has Component	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#hasComponent
Label	has component
Type of Term	Property
Inverse of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#isComposedOf
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: has Dynasty	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#hasDynasty
Label	has dynasty
Type of Term	Property
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Dynasty
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: has Emperor	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#hasEmperor
Label	has emperor
Type of Term	Property
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Emperor
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: has Function	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#hasFunction
Label	has function
Type of Term	Property
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Function
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: has Glaze-Color	

URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#hasGlaze-Color
Label	has glaze-color
Type of Term	Property
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Glaze-Color
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: is Component Of	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#isComponentOf
Label	is component of
Type of Term	Property
Inverse of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#hasComponent
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: is Depended On	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#isComponentOf
Label	is component of
Type of Term	Property
Inverse of	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#dependOn
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Component
Term Name: is Fired At	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#isFiredAt
Label	is fired at
Type of Term	Property
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Temperature
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: is Made Of	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#isMadeOf
Label	is made of
Type of Term	Property
Range	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Material
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: diameter Of Foot	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#diameterOfFoot
Label	diameter of foot
Type of Term	Property
Range	string
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vase
Term Name: diameter Of Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#diameterOfMouth
Label	diameter of mouth
Type of Term	Property
Range	string
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vase
Term Name: height	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#height
Label	height
Type of Term	Property
Range	string
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vase
Term Name: is Collected In	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#isCollectedIn

Label	is collected in
Type of Term	Property
Range	string
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: is Decorated By	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#isDecoratedBy
Label	is decorated by
Type of Term	Property
Range	string
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: is Produced In	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#isProducedIn
Label	is produced in
Type of Term	Property
Range	string
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#ClayVessel
Term Name: number Of Belly	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#numberOfBelly
Label	number of belly
Type of Term	Property
Range	string
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: number Of Mouth	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#numberOfMouth
Label	number of mouth
Type of Term	Property
Range	string
Domain	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#Vessel
Term Name: Concept Name	
URI	http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#conceptName
Label	concept name
Type of Term	Property
Comment	It is used to annotate the concept denoted by a class

Annex 3

TAO CI Ontology in Tedi

Tedi Onto-Dictionary on "Tao Ci" (en)

Date: 9 septembre 2020 - Time: 16:08:43 - Version: 2.1 - www.ontoterminology.com/tedi

search:

- arrow vase
- arrow vase I
- arrow vase II
- arrow vase III
- awl-handle vase
- basin
- bo
- bottle vase
- bowl
- box
- censer
- cong vase
- cong-shaped vase
- conjoined vase
- cup
- cylindrical vase
- dish
- double vase
- double-gourd vase
- double-gourd vase I

arrow vase I

Definition: Arrow vase with bulge belly, square mouth, slanting shoulder, and square foot.

Status: preferred

Equivalent(s):

- zh: 贯耳瓶 (preferred)

Concept: <Arrow Vase with belly bulge belly square mouth slanting shoulder with foot square foot>

essential characteristic(s): /for decoration/, /in clay/, /high temperature/, /one mouth/, /with handles/, /pierced handles/, /without lid/, /with neck/, /long neck/, /with belly/, /bulge belly/, /square mouth/, /slanting shoulder/, /with foot/, /square foot/,

a kind of: <Vase one mouth with handles with pierced handles without lid with neck long neck>

Comment: The "arrow vase I" is a new term (neoterm) introduced to distinguish the different types of arrow vases.

rdfs:seeAlso http://www.zhejiangmuseum.com/zjbwq/collection/collect_detail.html?id=3242

rdfs:seeAlso <https://www.dpm.org.cn/collection/ceramic/227009.html>

Illustration:



TAO CI Ontology in Tedi.

Essential Characteristics			
Point-of-view	Axis of analysis	Essential characteristic	Dependency
Material	Material	/in clay/	
		/in bronze/	
		/in jade/	
		/in silver/	
		/in wood/	
		/in glass/	
		/in gold/	
Function	Function	/for cooking/	
		/for decoration/	
		/for drawing water/	
		/for drinking/	
		/for eating	
		/for sacrifice/	
		/for snuff/	
		/for storing liquid/	
		/for storing solid/	
/for washing/			
Spout	Spout	/with spout/	
		/without spout/	
Temperature	Temperature	/high temperature/	
		/low temperature/	
Body shape	Body shape	/trumpet shaped body/	
		/not trumpet shaped body/	
Lid	Lid	/with lid/	
		/without lid/	
Mouth	Mouth	/with mouth/	
		/without mouth/	
	Number of mouths	/one mouth/	depends on /with mouth/
		/multi-mouth/	
	Size of mouth	/small mouth/	depends on /with mouth/
		/large mouth/	
	Shape of mouth top	/circle mouth/	depends on /with mouth/
		/square mouth/	
	Shape of mouth rim	/everted-rim mouth/	depends on /with mouth/
		/lip mouth/	
Shape of mouth	/brush washer shaped mouth/	depends on /with mouth/	
	/flower shaped mouth/		
	/garlic shaped mouth/		
	/plate shaped mouth/		
	Neck	/with neck/	
		/without neck/	
	Neck length	/long neck/	depends on /with neck/
		/short neck/	

Neck	Neck width	/slender neck/	depends on /with neck/
		/wide neck/	
	Neck bending	/straight neck/	depends on /with neck/
		/bending neck/	
Shoulder	Shoulder type	/circle shoulder/	
		/flat shoulder/	
		/folding shoulder/	
		/slanting shoulder/	
Handle	Handle	/with handle/	depends on /with handle/
		/without handle/	
	Handle type	/dragon-massk handle/	
		/dragon shaped handle/	
		/elephant shaped handle/	
		/fish shaped handle/	
		/halberd shaped handle/	
		/phoenix shaped handle/	
		/pierced handle/	
		/ribbon-shaped handle/	
/ru-yi shaped handle/			
Ring	Ring	/with ring/	depends on /with handle/
		/without ring/	
Belly	Belly depth	/deep belly/	
		/shallow belly/	
	Belly type	/bulge belly/	
		/cylindrical belly/	
		/drooping belly/	
		/flat belly/	
		/globular belly/	
		/gourd shaped belly/	
		/multi-prism belly/	
		/oblate belly/	
		/pear-shaped belly/	
		/round belly/	
		/spheroid belly/	
		/square belly/	
/swelling body tapering downwards/			
Bottom	Bottom	/flat bottom/	
		/not flat bottom/	
Foot	Foot	/with foot/	depends on /with foot/
		/without foot/	
	Foot type	/ring foot/	
		/concave foot/	
		/square foot/	
	Wall of foot	/convergence foot/	
		/outward foot/	
	Foot height	/straight foot/	
/high foot/			
		/low foot/	depends on /with foot/

Concepts		
Concept name: <Vessel in clay for sacrifice high temperature>		
Term	Preferred:	censer, 香炉
	Alternative:	
SubClassOf	Generic concept:	Vessel
	Essential characteristics:	/for sacrifice/, /high temperature/, /in clay/
Definition	Vessel in clay for sacrifice, fired at high temperature.	
Concept name: <Vessel for decoration trumpet shaped body in clay high temperature>		
Term	Preferred:	gu, 觚
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for decoration/, /high temperature/, /trumpet shaped body/, /in clay/
Definition	Vessel in clay for decoration, trumpet shaped body, fired at high temperature.	
Concept name: <Vessel for drinking in clay with spout high temperature>		
Term	Preferred:	jue, 爵
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for drinking/, /high temperature/, /with spout/, /in clay/
Definition	Vessel in clay for drinking, with spout, fired at high temperature.	
Concept name: <Vessel for drinking without spout high temperature in clay>		
Term	Preferred:	cup, 杯子
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for drinking/, /high temperature/, /without spout/, /in clay/
Definition	Vessel in clay for drinking, without spout, fired at high temperature.	
Concept name: <Vessel for eating in clay convergence mouth without spout high temperature>		
Term	Preferred:	bo, 钵
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for eating/, /high temperature/, /convergence mouth/, /without spout/, /in clay/
Definition	Vessel in clay for eating, with convergence mouth, without spout, fired at high temperature.	
Concept name: <Vessel for snuff high temperature in clay>		
Term	Preferred:	Snuff bottle, 鼻烟壶
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for snuff/, /high temperature/, /in clay/
Definition	Vessel in clay for snuff, fired at high temperature.	
Concept name: <Vessel for storing liquid with spout with handle in clay high temperature>		
Term	Preferred:	jug, 壶
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for storing liquid/, /high temperature/, /with spout/, /in clay/, /with handle/
Definition	Vessel in clay for storing liquid, with spout, with handle, fired at high temperature.	

Concept name: <Vessel for storing solid in clay with neck high temperature>		
Term	Preferred:	jar, 罐
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for storing solid/, /high temperature/, /with neck/, /in clay/
Definition	Vessel in clay for storing solid, with neck, fired at high temperature.	
Concept name: <Vessel for storing solid with lid without neck high temperature in clay>		
Term	Preferred:	box, 盒
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for storing solid/, /high temperature/, /with lid/, /in clay/, /without neck/
Definition	Vessel in clay for storing solid, with lid, without neck, fired at high temperature.	
Concept name: <Vessel for washing in clay without spout high temperature>		
Term	Preferred:	basin, 盆子
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for washing/, /high temperature/, /without spout/, /in clay/
Definition	Vessel in clay for washing, without spout, fired at high temperature.	
Concept name: <Vessel open mouth deep belly for eating high temperature in clay>		
Term	Preferred:	bowl, 碗
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for eating/, /high temperature/, /open mouth/, /in clay/, /deep belly/
Definition	Vessel in clay for storing solid, with lid, without neck, fired at high temperature.	
Concept name: <Vessel with belly shallow belly for eating open mouth high temperature in clay>		
Term	Preferred:	dish, 盘子
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for eating/, /high temperature/, /with belly/, /in clay/, /shallow belly/, /open mouth/
Definition	Vessel in clay for eating, with shallow belly, open mouth, fired at high temperature.	
Concept name: <Vessel with foot in clay with mouth with neck open mouth wide neck for storing liquid>		
Term	Preferred:	zun, 尊
	Alternative:	
SubClassOf	Generic concept:	<Vessel>
	Essential characteristics:	/for storing liquid/, /high temperature/, /with mouth/, /in clay/, /with foot/, /with neck/, /open mouth/, /wide neck/
Definition	Vessel in clay for storing liquid, fired at high temperature, with foot, open mouth, and wide neck.	
Concept name: <Vase multi-mouths with lid brush washer shaped mouth short neck slanting shoulder without handle bulge belly with foot ring foot>		
Term	Preferred:	twin vase, 双连瓶
	Alternative:	double vase, conjoined vase
SubClassOf	Generic concept:	<Vessel in clay for decoration high temperature>
	Essential characteristics:	/Multi mouths/, /with lid/, /brush washer shaped mouth/, /short neck/, /slanting shoulder/, /without handle/, /bulge belly/, /with foot/, /ring foot/

Definition	Vase with lid, multiple brush washer shaped mouths, short neck, slanting shoulder, bulge belly, and ring foot.	
Concept name: <Vessel for decoration in clay high temperature>		
Term	Preferred:	vase, 瓶子
	Alternative:	
SubClassOf	Generic concept:	<Vessel in clay for decoration high temperature>
	Essential characteristics:	/for decoration/, /high temperature/, /in clay/
Definition	Vessel in clay for decoration, fired at high temperature.	
Concept name: <Vase one mouth small mouth short neck circle shoulder without handle swelling body tapering downwards with foot ring foot>		
Term	Preferred:	plum vase, 梅瓶
	Alternative:	
SubClassOf	Generic concept:	<Vessel in clay for decoration high temperature>
	Essential characteristics:	/one mouth/, /small mouth/, /short neck/, /in clay/, /circle shoulder/, /without handle/, /swelling body tapering downwards/, /with foot/, /ring foot/
Definition	Vase with a small mouth, short neck, circle shoulder, swelling body tapering downwards, and ring foot.	
Concept name: <Plum Vase with lid>		
Term	Preferred:	plum vase I, 梅瓶 I
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth small mouth short neck circle shoulder without handle swelling body tapering downwards with foot ring foot>
	Essential characteristics:	/with lid/
Definition	Plum vase with lid.	
Concept name: <Plum Vase without lid lip mouth>		
Term	Preferred:	plum vase II, 梅瓶 II
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth small mouth short neck circle shoulder without handle swelling body tapering downwards with foot ring foot>
	Essential characteristics:	/lip mouth/, /without lid/
Definition	Plum vase without lid and with lip mouth..	
Concept name: <Vase one mouth small mouth short neck slanting shoulder gourd shaped belly>		
Term	Preferred:	double-gourd vase, 葫芦瓶
	Alternative:	
SubClassOf	Generic concept:	<Vessel for decoration in clay high temperature>
	Essential characteristics:	/one mouth/, /small mouth/, /short neck/, /slanting shoulder/, /gourd shaped belly/
Definition	Vase with a small mouth, short neck, slanting shoulder, and gourd shaped belly.	
Concept name: <Double-gourd Vase without handle without lid with foot ring foot>		
Term	Preferred:	double-gourd vase I, 葫芦瓶 I
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth small mouth short neck slanting shoulder gourd shaped belly>
	Essential characteristics:	/without handle/, /without lid/, /with foot/, /ring foot/
Definition	Double-gourd vase without handle, lid, with ring foot.	
Concept name: <Double-gourd Vase without lid with handle with ribbon-shape handles with foot square foot>		
Term	Preferred:	double-gourd vase II, 葫芦瓶 II
	Alternative:	

SubClassOf	Generic concept:	<Vase one mouth small mouth short neck slanting shoulder gourd shaped belly>
	Essential characteristics:	/without lid/, /with handle/, /with ribbon-shape handle/, /with foot/, /square foot/
Definition	Double-gourd vase with ribbon-shape handle, square foot, and without lid.	
Concept name: <Double-gourd Vase with lid without handles with foot ring foot>		
Term	Preferred:	double-gourd vase III, 葫芦瓶 III
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth small mouth short neck slanting shoulder gourd shaped belly>
	Essential characteristics:	/with lid/, /without handle/, /with foot/, /ring foot/
Definition	Double-gourd vase with lid, ring foot, and without handle.	
Concept name: <Vase one mouth garlic shaped mouth without lid with foot ring foot>		
Term	Preferred:	garlic-head vase, 蒜头瓶
	Alternative:	garlic vase
SubClassOf	Generic concept:	<Vessel for decoration in clay high temperature>
	Essential characteristics:	/one mouth/, /garlic shaped mouth/, /without lid/, /with foot/, /ring foot/.
Definition	Vase with a garlic shaped mouth and ring foot.	
Concept name: <Garlic-head Vase short neck circle shoulder with handle with ru-yi shaped handle globular belly>		
Term	Preferred:	garlic-head vase I, 蒜头瓶 I
	Alternative:	
SubClassOf	Generic concept:	< Vase one mouth garlic shaped mouth without lid with foot ring foot >
	Essential characteristics:	/short neck/, /circle shoulder/, /with handle/, /with ru-yi shaped handle/, /globular belly/.
Definition	Garlic-head vase with short neck, circle shoulder, with ru-yi shaped handles and globular belly.	
Concept name: <Garlic-head Vase slender neck long neck slanting shoulder bulge belly>		
Term	Preferred:	garlic-head vase II, 蒜头瓶 II
	Alternative:	
SubClassOf	Generic concept:	< Vase one mouth garlic shaped mouth without lid with foot ring foot >
	Essential characteristics:	/slender neck/, /long neck/, /slanting shoulder/, /bulge belly/
Definition	Garlic-head vase with slender and long neck, slanting shoulder, and bulge belly.	
Concept name: <Vase multi-mouths without lid lip mouth bending neck without handle bulge belly with foot ring foot>		
Term	Preferred:	Double-tube vase, 多管瓶
	Alternative:	
SubClassOf	Generic concept:	<Vessel for decoration in clay high temperature>
	Essential characteristics:	/multi-mouths/, /without lid/, /lip mouth/, /bending neck/, /without handle/, /bulge belly/, /with foot/, /ring foot/
Definition	Vase with multiple lip mouths, bending neck, bulge belly, and ring foot.	
Concept name: <Vase one mouth straight neck circle shoulder without handle globular belly>		
Term	Preferred:	vault-of-heaven vase, 天球瓶
	Alternative:	globular vase
SubClassOf	Generic concept:	<Vessel for decoration in clay high temperature>
	Essential characteristics:	/one mouth/, /straight neck/, /circle shoulder/, /without handle/, /globular belly/

Definition	Vase with a mouth, straight neck, circle shoulder, and globular belly.	
Concept name: <Vault-of-heaven vase small mouth lip mouth without foot>		
Term	Preferred:	vault-of-heaven vase I, 天球瓶 I
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth straight neck circle shoulder without handle globular belly >
	Essential characteristics:	/small mouth/, /lip mouth/, /without foot/
Definition	Vault-of-heaven vase with a small lip mouth and without foot.	
Concept name: <Vault-of-heaven vase straight mouth with foot concave foot>		
Term	Preferred:	vault-of-heaven vase II, 天球瓶 II
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth straight neck circle shoulder without handle globular belly >
	Essential characteristics:	/straight mouth/, /with foot/, /concave foot/
Definition	Vault-of-heaven vase with a straight mouth and concave foot.	
Concept name: <Vase one mouth with handle with pierced handle without lid with neck long neck>		
Term	Preferred:	arrow vase, 贯耳瓶
	Alternative:	
SubClassOf	Generic concept:	<Vessel for decoration in clay high temperature>
	Essential characteristics:	/one mouth/, /with handle/, /with pierced handle/, /without lid/, /with neck/, /long neck/
Definition	Vase with pierced handles and long neck.	
Concept name: <Arrow Vase with belly bulge belly square mouth slanting shoulder with foot square foot>		
Term	Preferred:	arrow vase I, 贯耳瓶 I
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth with handle with pierced handle without lid with neck long neck >
	Essential characteristics:	/with belly/, /bulge belly/, /square mouth/, /slanting shoulder/, /with foot/, /square foot/
Definition	Arrow vase with bulge belly, square mouth, slanting shoulder, and square foot.	
Concept name: <Arrow Vase straight mouth slanting shoulder with belly bulge belly with foot ring foot>		
Term	Preferred:	arrow vase II, 贯耳瓶 II
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth with handle with pierced handle without lid with neck long neck >
	Essential characteristics:	/straight mouth/, /slanting shoulder/, /with belly/, /bulge belly/, /with foot/, /ring foot/
Definition	Arrow vase with straight mouth, slanting shoulder, bulge belly, and ring foot.	
Concept name: <Arrow Vase with belly swelling body tapering downwards straight mouth one mouth folding shoulder with foot ring foot>		
Term	Preferred:	arrow vase III, 贯耳瓶 III
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth with handle with pierced handle without lid with neck long neck >
	Essential characteristics:	/with belly/, /swelling body tapering downwards/, /straight mouth/, /one mouth/, /folding shoulder/, /with foot/, /ring foot/
Definition	Arrow vase with swelling body tapering downwards, straight mouth, folding shoulder, and ring foot.	
Concept name: <Vase one mouth without lid flower shaped mouth slender neck without handle slanting shoulder with foot ring foot>		

Term	Preferred:	flower-mouth vase, 花口瓶
	Alternative:	
SubClassOf	Generic concept:	<Vessel for decoration in clay high temperature>
	Essential characteristics:	/one mouth/, /without lid/, /flower shaped mouth/, /slender neck/, /without handle/, /slanting shoulder/, /with foot/, /ring foot/
Definition	Vase with a flower shaped mouth, slender neck, slanting shoulder, and ring foot.	
Concept name: <Flower-mouth Vase long neck globular belly>		
Term	Preferred:	flower-mouth vase I, 花口瓶 I
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth without lid flower shaped mouth slender neck without handle slanting shoulder with foot ring foot >
	Essential characteristics:	/long neck/, /globular belly/
Definition	Flower-mouth vase with long neck and globular belly.	
Concept name: <Flower-mouth Vase short neck round belly with foot outward foot>		
Term	Preferred:	flower-mouth vase II, 花口瓶 II
	Alternative:	
SubClassOf	Generic concept:	<Vase one mouth without lid flower shaped mouth slender neck without handle slanting shoulder with foot ring foot >
	Essential characteristics:	/short neck/, /round belly/, /with foot/, /outward foot/
Definition	Flower-mouth vase with short neck, round belly, and outward foot.	
Concept name: <Vase one mouth without lid lip mouth long neck slender neck slanting shoulder without handle oblate belly with foot ring foot>		
Term	Preferred:	water-chestnut vase, 荸荠瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/one mouth/, /without lid/, /lip mouth/, /long neck/, /slender neck/, /slanting shoulder/, /without handle/, /oblate belly/, /with foot/, /ring foot/
Definition	Vase with a lip mouth, slender and long neck, slanting shoulder, oblate belly, and ring foot.	
Concept name: <Vase one mouth without lid long neck slender neck slanting shoulder without handle drooping belly with foot ring foot>		
Term	Preferred:	gall-bladder vase, 胆式瓶
	Alternative:	gall-shaped vase
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/one mouth/, /without lid/, /long neck/, /slender neck/, /slanting shoulder/, /without handle/, /drooping belly/, /with foot/, /ring foot/
Definition	Vase a mouth, long and slender neck, slanting shoulder, drooping belly, and ring foot.	
Concept name: <Gall-bladder Vase small mouth>		
Term	Preferred:	gall-bladder vase I, 胆式瓶 I
	Alternative:	
SubClassOf	Generic concept:	< Vase one mouth without lid long neck slender neck slanting shoulder without handle drooping belly with foot ring foot >
	Essential characteristics:	/small mouth/
Definition	Gall-bladder vase with a small mouth.	
Concept name: <Gall-bladder Vase straight mouth>		

Term	Preferred:	gall-bladder vase II, 胆式瓶 II
	Alternative:	
SubClassOf	Generic concept:	< Vase one mouth without lid long neck slender neck slanting shoulder without handle drooping belly with foot ring foot >
	Essential characteristics:	/straight mouth/
Definition	Gall-bladder vase with a straight mouth.	
Concept name: <Vase one mouth without lid outward mouth short neck slanting shoulder without handle cylindrical belly without foot flat bottom>		
Term	Preferred:	elephant leg vase, 象腿瓶
	Alternative:	cylindrical vase, 筒瓶
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/one mouth/, /without lid/, /outward mouth/, /short neck/, /slanting shoulder/, /without handle/, /cylindrical belly/, /without foot/, /flat bottom/
Definition	Vase with an outward mouth, short neck, slanting shoulder, cylindrical belly, without foot, and flat bottom.	
Concept name: <Vase one mouth without lid outward mouth slender neck long neck slanting shoulder without handle globular belly with foot ring foot>		
Term	Preferred:	reward vase, 赏瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/one mouth/, /without lid/, /outward mouth/, /slender neck/, /long neck/, /slanting shoulder/, /without handle/, /globular belly/, /with foot/, /ring foot/
Definition	Vase with an outward mouth, slender and long neck, slanting shoulder, globular belly, and ring foot.	
Concept name: <Vase one mouth without lid plate shaped mouth straight neck folding shoulder without handle cylindrical belly with foot ring foot>		
Term	Preferred:	rouleau vase, 圆棒槌瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/one mouth/, /without lid/, /plate shaped mouth/, /straight neck/, /folding shoulder/, /without handle/, /cylindrical belly/, /with foot/, /ring foot/
Definition	Vase with a plate shaped mouth, straight neck, folding shoulder, cylindrical belly, and ring foot.	
Concept name: <Vase one mouth without lid slanting shoulder without handle bulge belly with foot ring foot>		
Term	Preferred:	olive-shaped vase, 橄榄瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/one mouth/, /without lid/, /slanting shoulder/, /without handle/, /bulge belly/, /with foot/, /ring foot/
Definition	Vase with a mouth, slanting shoulder, bulge belly, ring foot.	
Concept name: <Olive-shaped Vase outward mouth slender neck long neck with foot outward foot>		
Term	Preferred:	olive-shaped vase I, 橄榄瓶 I
	Alternative:	
SubClassOf	Generic concept:	< Vase one mouth without lid slanting shoulder without handle bulge belly with foot ring foot >
	Essential characteristics:	/outward mouth/, /slender neck/, /long neck/, /with foot/, /outward foot/

Definition	Olive-shaped vase with an outward mouth, slender and long neck, and outward foot.	
Concept name: <Olive-shaped Vase straight mouth short neck>		
Term	Preferred:	olive-shaped vase II, 橄榄瓶 II
	Alternative:	
SubClassOf	Generic concept:	< Vase one mouth without lid long neck slender neck slanting shoulder without handle drooping belly with foot ring foot >
	Essential characteristics:	/straight mouth/, /short neck/
Definition	Olive-shaped vase with a straight mouth, short neck.	
Concept name: <Vase one mouth without lid small mouth slender neck long neck slanting shoulder without handle globular belly without foot flat bottom>		
Term	Preferred:	oil-hammer vase, 油锤瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/one mouth/, /without lid/, /small mouth/, /slender neck/, /long neck/, /slanting shoulder/, /without handle/, /globular belly/, /without foot/, /flat bottom/
Definition	Vase with a small mouth, slender and long neck, slanting shoulder, globular belly, without foot, and flat bottom.	
Concept name: <Vase one mouth without lid small mouth slender neck with neck long neck slanting shoulder without handle with belly globular belly with foot ring foot>		
Term	Preferred:	awl-handle vase, 锥把瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/one mouth/, /without lid/, /small mouth/, /slender neck/, /long neck/, /slanting shoulder/, /without handle/, /with belly/, /globular belly/, /with foot/, /ring foot/
Definition	Vase with a small mouth, slender and long neck, slanting shoulder, globular belly, and ring foot.	
Concept name: <Vase one mouth without lid straight mouth slender neck with handle with ru-yi shaped handle without ring circle shoulder oblate belly with foot ring foot>		
Term	Preferred:	moon shaped vase, 宝月瓶
	Alternative:	moon flask
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/one mouth/, /without lid/, /straight mouth/, /slender neck/, /with handle/, /with ru-yi shaped handle/, /without ring/, /circle shoulder/, /oblate belly/, /with foot/, /ring foot/
Definition	Vase with a straight mouth, slender neck, ru-yi shaped handles, without ring, circle shoulder, oblate belly, and ring foot.	
Concept name: <Vase without lid one mouth outward mouth long neck slanting shoulder without handle bulge belly with foot ring foot>		
Term	Preferred:	long-necked vase, 长颈瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/without lid/, /one mouth/, /outward mouth/, /long neck/, /slanting shoulder/, /without handle/, /bulge belly/, /with foot/, /ring foot/
Definition	Vase with an outward mouth, long neck, slanting shoulder, bulge belly, and ring foot.	
Concept name: <Vase without lid one mouth outward mouth short neck flat shoulder without handle square belly with foot square foot>		

Term	Preferred:	square rouleau vase, 方棒槌瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/without lid/, /one mouth/, /outward mouth/, /short neck/, /flat shoulder/, /without handle/, /square belly/, /with foot/, /square foot/
Definition	Vase with an outward mouth, short neck, flat shoulder, square belly, and square foot.	
Concept name: <Vase without lid one mouth outward mouth short neck slanting shoulder without handle cylindrical belly with foot ring foot>		
Term	Preferred:	lantern-shaped vase, 灯笼瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/without lid/, /one mouth/, /outward mouth/, /short neck/, /slanting shoulder/, /without handle/, /cylindrical belly/, /with foot/, /ring foot/
Definition	Vase with an outward mouth, short neck, slanting shoulder, cylindrical belly, and ring foot.	
Concept name: <Vase without lid one mouth plate shaped mouth long neck with handle with fish shaped handle with ring slanting shoulder drooping belly with foot high foot ring foot outward foot>		
Term	Preferred:	loosing ring vase, 活环瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/without lid/, /one mouth/, /plate shaped mouth/, /long neck/, /with handle/, /with fish shaped handle/, /with ring/, /slanting shoulder/, /drooping belly/, /with foot/, /high foot/, /ring foot/, /outward foot/
Definition	Vase with a plate shaped mouth, long neck, fish shaped handles, ring, slanting shoulder, drooping belly, and high and ring and outward foot.	
Concept name: <Vase without lid outward mouth short neck slanting shoulder without handle swelling body tapering downwards with foot ring foot>		
Term	Preferred:	willow-leaf-shaped vase, 柳叶瓶
	Alternative:	美人肩
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/without lid/, /outward mouth/, /short neck/, /slanting shoulder/, /without handle/, /swelling body tapering downwards/, /with foot/, /ring foot/
Definition	Vase with an outward mouth, short neck, slanting shoulder, swelling body tapering downwards, and ring foot.	
Concept name: <Vase without lid outward mouth slender neck slanting shoulder without handle pear-shaped belly with foot ring foot>		
Term	Preferred:	pear-shaped vase, 玉壶春瓶
	Alternative:	
SubClassOf	Generic concept:	< Vessel for decoration in clay high temperature >
	Essential characteristics:	/without lid/, /outward mouth/, /slender neck/, /slanting shoulder/, /without handle/, /pear-shaped belly/, /with foot/, /ring foot/.
Definition	Vase with an outward mouth, slender neck, slanting shoulder, pear-shaped belly, and ring foot.	
Concept name: <Vase one mouth without lid small mouth short neck flat shoulder without handle square belly with foot ring foot>		
Term	Preferred:	cong-shaped vase, 琮式瓶

	Alternative:	
	Generic concept:	<Vessel for decoration in clay high temperature>
SubClassOf	Essential characteristics:	/without lid/, /one mouth/, /small mouth/, /short neck/, /flat shoulder/, /without handle/, /square belly/, /with foot/, /ring foot/
Definition	Vase with a small mouth, short neck, flat shoulder, square belly, and ring foot.	

Annex 4

Résumé étendu en français

Terminologie et Ontologie pour l'Héritage Culturel : Application aux vases en céramique Chinois

Mots clés : Héritage Culturel, Terminologie, Ontologie, Ontoterminologie, Données liées et ouvertes, Web Sémantique, Protégé

1. Introduction

On peut définir le Patrimoine (Héritage) Culturel comme l'ensemble des biens hérités des générations passées, qu'ils soient matériels ou immatériels, relatifs à la culture d'un groupe ou d'une société. La mise à disposition au format numérique de ces biens participe à la préservation et à la diffusion de l'héritage culturel. Parmi les biens matériels les plus emblématiques, les vases occupent une place toute particulière, témoins omniprésents d'une société et d'une culture – il suffit de penser aux vases de la Grèce antique et à la richesse de leurs décors¹⁴² [Mertens 2010].

Dans le cadre de notre travail nous nous sommes intéressés aux vases en céramique chinois des dynasties Ming (1368-1644) et Qing (1644-1911) utilisés à des fins décoratives et dont il existe de nombreuses collections réparties dans différents musées en Chine. Si certaines de ces collections ont été numérisées, elles sont rarement accessibles dans un format ouvert et restent isolées. De plus, l'absence de terminologies clairement identifiées est un obstacle à la communication et au partage des connaissances.

Le projet Tao Ci (céramique en chinois) a été initié en 2017 dans le cadre du doctorat de Wei Tong, mené en codirection par l'Université Savoie Mont-Blanc et l'Université de Liaocheng (Chine). Ce projet vise à répondre à cette problématique par la mise en œuvre de pratiques relevant du web sémantique et de l'ingénierie des connaissances, et plus particulièrement par la construction sous un format du W3C d'une ontoterminologie dédiée aux vases chinois des dynasties Ming et Qing, c'est-à-dire la construction d'une conceptualisation du domaine (ontologie) et d'une terminologie bilingue (anglais-chinois) sous la forme d'un dictionnaire électronique.

¹⁴² "How to Read Greek Vases". Joan R. Mertens, The Metropolitan Museum of Art, Yale University Press, 2010. La poterie peinte grecque, en dehors de ses fonctions utilitaires, a offert aux artistes un moyen de dépeindre leurs mythes et les détails de leur existence quotidienne.

Face à la difficulté qu'ont les experts dans la manipulation d'environnements comme Protégé¹⁴³ dans la construction d'ontologies au format du W3C¹⁴⁴, nous avons décidé de tenir compte de la façon de penser des experts dans un domaine similaire [Roche & Papadopoulou 2019] et des principes terminologiques préconisés par les normes ISO [ISO 1087], [ISO 704]. Dans ce cadre, la notion de caractéristique essentielle tient une place prépondérante. La définition aristotélicienne du terme en genre prochain et différence spécifique repose sur elle, tout comme la définition du concept comme combinaison unique de caractéristiques [ISO 1087]. Cela n'est pas sans conséquence sur la méthodologie de construction de l'ontologie et son expression dans Protégé. La notion de caractéristique essentielle n'existant pas en logique de description, elle devra donc être traduite.

Ce résumé étendu est structuré de la façon suivante. La deuxième section présente le domaine et la façon dont a été construit le « jeu de données », c'est-à-dire les vases qui serviront à la fois à la construction, l'illustration et la validation de l'ontologie. La troisième section est dédiée au rappel des objectifs du projet Tao Ci et aux « questions de compétences », notre ontologie devra y répondre. Un état de l'art nous permettra de lister les ressources auxquelles l'ontologie Tao Ci sera liée. Nous verrons ensuite la méthodologie que nous avons suivie, en particulier pour l'identification des caractéristiques essentielles qui reposera à la fois sur la comparaison d'objets (vases) tant d'un point de vue fonctionnel que structurel, et sur une analyse morphologique des termes chinois, les caractères les composant étant porteurs de sens au regard des connaissances qu'ils désignent. Nous verrons ensuite comment traduire les combinaisons de caractéristiques essentielles (qui définissent des concepts) sous la forme de restrictions de propriétés en Protégé. Il restera enfin à évaluer l'ontologie ainsi construite. Nous concluons en rappelant l'importance d'une démarche guidée par les termes et les caractéristiques essentielles.

2. Les vases des dynasties Ming et Qing

2.1 Les dynasties Ming et Qing

La civilisation chinoise est une des civilisations les plus anciennes. La diversité et la complexité des vases chinois est une des illustrations de la richesse de la culture chinoise. Dans ce contexte, nous nous sommes intéressés aux vases en céramique chinois, et plus précisément aux récipients en argile cuite à haute température utilisés à des fins décoratives, des dynasties Ming et Qing [冯先铭, 2002], et dont il existe de nombreuses collections réparties dans différents musées en Chine. Les vases de ces deux dynasties rentrent dans une même classification (à l'exception des vases "reward vase" (赏瓶)). Il se distinguent principalement par leur décoration (voir figures 1 et 2).

¹⁴³ Protégé est l'environnement de construction d'ontologies le plus utilisé. Développé par l'Université de Stanford, ouvert et libre, il bénéficie d'une importante communauté d'utilisateurs. <https://protege.stanford.edu/>

¹⁴⁴ "As the group that developed Protégé, the most widely used ontology editor, we are keenly aware of how difficult the users perceive this task to be" [Horridge et al. 2013]

Les céramiques de la dynastie Ming (1368-1644) étaient célèbres pour la variété de leurs motifs et pour la hardiesse de leur forme et de leur décoration¹⁴⁵. Déjà à l'époque de la dynastie Tang (618-907) et de la dynastie Song (960-1279), il existait de nombreux fours célèbres et de nombreux types de récipients en céramique. Dès le début de la dynastie Ming, le four de Jingdezhen est progressivement devenu le lieu de production le plus important, les récipients en céramique représentaient alors la plus haute qualité. Entre 1350 et 1750, Jingdezhen était un centre de production « mondial »¹⁴⁶.



Figure 1 : “Double-gourd vase I” (葫芦瓶 I), dynastie Ming

<https://www.dpm.org.cn/collection/ceramic/227394.html>

Les céramiques de la dynastie Qing (1644-1911) étaient, quant à elles, célèbres pour leurs décorations polychromes, leurs paysages délicatement peints, leurs motifs d'oiseaux et de fleurs ainsi que leurs émaux multicolores. L'apogée de la production chinoise de céramique a eu lieu sous les règnes des empereurs Kangxi (1661-1722), Yongzheng (1722-1735) et Qianlong (1735-1796), au cours desquels des améliorations ont été constatées dans presque tous les types de céramique, y compris les pièces bleues et blanches, les pièces polychromes, les pièces monochromes, etc¹⁴⁷. Pendant la dynastie Qing, les potiers ont commencé à utiliser des couleurs vives pour orner les assiettes et les vases de scènes minutieusement peintes.



Figure 2 : “Double-gourd vase I” (葫芦瓶 I), dynastie Qing

<https://www.dpm.org.cn/collection/ceramic/227612.html>

2.2 La Collection de vases

La première étape de notre travail a consisté à sélectionner l'ensemble des vases à étudier. Cet ensemble devait être suffisamment représentatif de la richesse du domaine sans être trop conséquent, le but premier étant de définir l'ontologie et non de la « peupler » d'objets. Pour le choix des vases, nous avons adopté trois critères. Les deux premiers portent sur la sélection du musée qui devait remplir les conditions suivantes : la collection de céramiques devait être reconnue comme une référence dans le domaine en Chine et les informations sur la collection être accessibles au public et suffisamment précises pour permettre la construction d'une ontologie. Le troisième principe a été de sélectionner des objets aussi différents que possible, selon leur forme, la technique de fabrication, la décoration, etc. tout en étant représentatifs (prototypiques) des éléments de leur classe. Ainsi, cent quarante-neuf objets ont été sélectionnés dans différents musées en Chine représentant 25 types de vases différents. Quarante-vingt-dix-sept objets

¹⁴⁵ <http://factsanddetails.com/china/cat7/sub40/item258.html#chapter-11>

¹⁴⁶ « La production de porcelaine à Jingdezhen a fait de la ville la capitale mondiale de la porcelaine, ce qu'elle est sans doute encore » He Li (trad. Paul Delifer, photogr. Kazuhiro Tsuruta), *La Céramique chinoise* [« Chinese Ceramics »], Paris, Thames & Hudson, 2006

¹⁴⁷ <https://www.comuseum.com/ceramics/qing/>

proviennent du Palace Museum¹⁴⁸ qui possède la plus importante collection de céramiques. Vingt-deux objets proviennent du Musée national de Chine¹⁴⁹, vingt-quatre du Musée de Guangdong¹⁵⁰. Quatre objets proviennent du Musée de Shanghai¹⁵¹ et deux vases du Musée de la Capitale¹⁵².

3. Objectifs

Le projet Tao Ci vise deux objectifs. Le premier est la construction d'une modélisation des vases en céramique des dynasties Ming et Qing sous la forme d'une ontologie au format du web sémantique qui soit ouverte et partageable. Ce premier objectif n'inclut pas une phase de peuplement de l'ontologie. Le jeu de données, constitué de vases « prototypes » de leur classe, n'est là qu'à des fins de construction et d'illustration. Le deuxième objectif est la définition d'une terminologie bilingue anglais-chinois de ces vases sous la forme d'un dictionnaire électronique accessible sur internet. Ontologie et terminologie sont liées au sens où un terme est une « désignation verbale d'un concept » [ISO 1087-1]. Le résultat de leur mise en relation est une ontoterminologie [Roche 2007]. On se place donc dans le cadre d'une terminologie où on s'intéresse, non pas à la signification des termes construite en discours, mais à ce qu'ils désignent en dehors de tout discours (définitions dites de « chose »). Il n'y a pas non plus de phase d'extraction de candidats termes. En effet, les 25 termes désignant les différents types de vases de notre étude sont connus des experts et directement accessibles à partir de lexiques tels que le "Chinese-English Glossary of Cultural Relics and Archeology" [王殿明 & 杨绮华, 2005] et des sites web des musées : "贯耳瓶" ("arrow vase"), "锤把瓶" ("awl-handle-shaped vase"), "玉壶春瓶" ("bottle Vase"), "软棒槌瓶" ("circle rouleau vase"), etc. Néanmoins, on pourra être amené à introduire de nouveaux termes (néologismes) afin de pouvoir désigner des types de vases que la conceptualisation aurait introduits et qu'il serait utile de nommer, par exemple les différents types de "garlic-head vase" (蒜头瓶).

Enfin, l'écriture de « questions de compétences » a permis de préciser les spécifications de l'ontologie [Ren et al. 2014]. Nous nous sommes arrêtés à une douzaine de questions (table 1, les variables commencent par un point d'interrogation, les références à un individu par l'article indéfini en anglais).

QC	Questions de compétences	Classe(s)	Relation
1	Quels sont les différents types de vase ?	Vase	?vase <i>isA</i> Vase
2	Dans quel matériau est fait un vase ?	Vase, Material	aVase <i>madeOf</i> ?material
3	De quelle couleur est le vernis du vase	Vase, GlazeColor	aVase <i>glazeColor</i> ?glazecolor
4	A quelle dynastie appartient le vase ?	Vase, Dynasty	aVase <i>hasDynasty</i> ?dynasty
5	A quel empereur appartient le vase ?	Vase, Emperor	aVase <i>hasEmperor</i> ?emperor
6	Quels sont les termes anglais et chinois désignant les vases ?	Vase	?vase <i>label</i> ?string
7	Quels sont les composants d'un vase ?	Vase, Component	aVase <i>hasComponent</i> ?component
8	Quelle est la fonction d'un vase ?	Vase, Function	aVase <i>hasFunction</i> ?function

¹⁴⁸ <https://www.dpm.org.cn/Home.html>

¹⁴⁹ <http://www.chnmuseum.cn/>

¹⁵⁰ <http://www.gdmuseum.com/>

¹⁵¹ <https://www.shanghaimuseum.net/museum/frontend/>

¹⁵² <http://www.capitalmuseum.org.cn/>

9	A quelle dynastie appartient l'empereur ?	Emperor, Dynasty	anEmperor <i>belongsTo</i> ?dynasty
10	A quelle collection appartient le vase ?	Vase, Collection	aVase <i>collectedIn</i> ?collection
11	Dans quel four a été produit le vase ?	Vase	aVase <i>producedIn</i> ?string
12	Quels sont les vases produits sous la Dynastie Qing ?	Vase, Dynasty	?vase <i>hasDynasty</i> Qing

Table 1. Les questions de compétences pour l'ontologie Tao Ci

4. State-of-art

L'ouverture de données cultures sur internet s'appuie sur les langages du W3C construits autour de RDF¹⁵³ et RDFS¹⁵⁴. Citons en particulier le vocabulaire DC¹⁵⁵ (Dublin Core) qui propose, dans sa version de base, pour la description de ressources aussi bien physiques (livres, objets culturels, etc.) que numériques (vidéo, images, sites web, etc.), 15 métadonnées¹⁵⁶ : titre, auteur, sujets, format, etc. Le vocabulaire SKOS¹⁵⁷ (Simple Knowledge Organization System) permet la représentation, le partage et la mise en relation de systèmes de connaissances simples tels que les thésaurus, les taxonomies ou des systèmes de classification. Le langage OWL¹⁵⁸ (Web Ontology Language) est destiné, quant à lui, à la construction de systèmes de connaissances complexes définis de façon formelle permettant de vérifier leur consistance. OWL est le langage « incontournable » du W3C pour la construction d'ontologies de domaine.

En dehors de ces langages généralistes, il faut citer les vocabulaires dédiés à la représentation de biens culturels. Dans la mesure ils définissent les concepts et les relations nécessaires à la représentation de ce type de connaissances, ils sont également considérés comme des ontologies de domaine. Ainsi, CIDOC CRM¹⁵⁹ (Comité International pour la DOCUMENTATION Conceptual Reference Model) est devenu un standard international pour le partage de données relatives au patrimoine culturel. EDM¹⁶⁰ (Europeana Data Model) vise le même objectif d'harmonisation de ressources numériques issues des institutions culturelles (bibliothèques, musées, etc.) de l'Union Européenne accessibles à travers la plateforme Europeana¹⁶¹ [Doerr et al., 2010].

Parmi les ressources disponibles sur lesquelles le projet Tao Ci peut s'appuyer avec profit, citons le thésaurus AAT¹⁶² (Art & Architecture Thesaurus) portant sur l'art, l'architecture et la culture [Soergel, 1995]. On trouve ainsi le terme "arrow vase" défini comme un « type of globular Chinese vase with a long

¹⁵³ RDF, pour Resource Description Framework, est un format d'échange de données pour le Web : <https://www.w3.org/RDF/>

¹⁵⁴ RDFS, pour RDF Schema, permet d'étendre RDF par la définition de classes et de propriétés afin d'organiser les ressources RDF : <https://www.w3.org/TR/rdf-schema/>

¹⁵⁵ <https://www.w3.org/wiki/DublinCore>

¹⁵⁶ Les langages de la famille RDF sont appelés indistinctement *vocabulaires*, *terminologies*, *ontologies*, « There is no clear division between what is referred to as "vocabularies" and "ontologies". » <https://www.w3.org/standards/semanticweb/ontology>, et les termes qui les composent des métadonnées, « Metadata is machine understandable information for the Web » <https://www.w3.org/Metadata/>

¹⁵⁷ <https://www.w3.org/TR/2009/REC-skos-reference-20090818/>

¹⁵⁸ <https://www.w3.org/OWL/>

¹⁵⁹ <http://www.cidoc-crm.org/>. CIDOC CRM a fait l'objet d'une norme internationale ISO en 2006 (dernière version [ISO 21127:2014](https://www.iso.org/standard/51222.html))

¹⁶⁰ <https://pro.europeana.eu/page/edm-documentation>

¹⁶¹ <https://www.europeana.eu/fr>

¹⁶² <https://www.getty.edu/research/tools/vocabularies/aat/about.html#scope>

cylindrical neck at the top of which are two tubular loops or lugs. ». Le projet Kerameikos¹⁶³ est un “collaborative project dedicated to defining the intellectual concepts of pottery following the tenets of linked open data and the formulation of an ontology for representing and sharing ceramic data across disparate data systems.” [Gruber & Smith, 2014]. Ontoceramic est une ontologie OWL construite à des fins de catalogage et de classification des céramiques anciennes « an OWL 2 ontology for cataloguing and classifying ancient ceramics » sur par exemple leur forme [Cantone et al., 2015]. Enfin, Lekythos¹⁶⁴ est un projet de construction d’ontologies des vases de la Grèce antique développé au sein de notre laboratoire.

L’ontologie de l’Ingénierie des Connaissances a donné lieu à différentes définitions [Gruber 1993] [Ushold & Gruninger 1996] [Staab & Studer 2009] que passe en revue l’article « What Is an Ontology ? » [Guarino et al. 2009]. Nous les résumerons en disant qu’une ontologie est une conceptualisation partagée d’un domaine exprimée dans un langage compréhensible par un ordinateur. Elle a également donné lieu à différentes méthodes de construction s’appuyant sur des phases de spécification, acquisition des connaissances, intégration, implémentation, évaluation, etc. Citons parmi ces méthodes, Methontology [Fernández-López et al., 1997], On-To-Knowledge [Sure et al., 2004], NeOn [Suárez-Figueroa et al., 2015].

A notre connaissance, il n’existe aucune ontologie formelle des vases en céramique des Dynasties Ming et Qing.

5. Une démarche guidée par les termes et les caractéristiques essentielles

Si la construction d’une ontologie suit un cycle de vie composé de plusieurs étapes [Fernández-López et al., 1997], on peut être amené à adapter certaines d’entre elles et à en introduire de nouvelles afin de tenir compte des spécificités du domaine. La théorie du concept qui sous-tend l’ontologie peut également fortement impacter la méthodologie de construction. Ainsi, les principes de l’ISO sur la Terminologie pour lesquels un terme est une « désignation verbale d’un concept » [ISO 1087] et un concept défini par une « combinaison unique de caractéristiques » [ISO 1087] nous ont amenés à suivre une démarche guidée par les termes et les caractéristiques essentielles, démarche reprise avec profit dans des travaux menés en Humanités Numériques [Roche & Papadopoulou, 2019]. La recherche des caractéristiques essentielles devient alors la question centrale à laquelle s’ajoute celle de leur combinaison pour la définition de concepts. Le résultat est une méthodologie en 7 étapes : spécification (périmètre, objectifs, questions de compétences), identification des termes et des objets (vases), identification des caractéristiques essentielles, définition des concepts guidée par les termes, implémentation, intégration de ressources externes, évaluation.

5.1 Caractéristiques essentielles

Une caractéristique essentielle est une caractéristique telle que, retranchée de la chose, la chose n’est plus ce qu’elle est. Ainsi, un « arrow vase » sans anses percées n’est plus un « arrow vase ». L’identification des

¹⁶³ <http://kerameikos.org/>

¹⁶⁴ <http://o4dh.com/lekythos>

caractéristiques essentielles repose sur deux approches, la première porte sur la comparaison des objets entre eux, la deuxième sur une analyse morphologique des termes chinois.

5.1.1 Différences entre objets

Identifier ce qu'on considère comme des différences essentielles entre objets est un moyen efficace pour identifier les caractéristiques essentielles. Ces différences peuvent être d'ordre fonctionnel, comme par exemple les vases pour le transport, le stockage, la décoration, etc. ; d'ordre matériel, en argile, en bronze, en jade ; d'ordre structurel, avec pied, sans pied, avec ou sans anses, etc. L'étude des parties d'un objet joue un rôle fondamental dans cette démarche [Gerstl & Pribbenow, 1996].

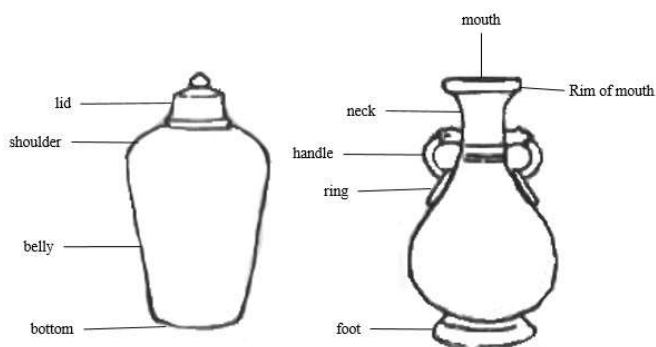


Figure 3 : Composants d'un vase en céramique

Ainsi, les vases chinois se subdivisent en vases avec anses et en vases sans anses, correspondant aux caractéristiques essentielles /avec anses/ et /sans anses/¹⁶⁵. Les vases avec anses se subdivisent à nouveau selon le type de anses /dragon-shaped handle/, /elephant-shaped handle/, /pierced handle/, etc. (figure 4).

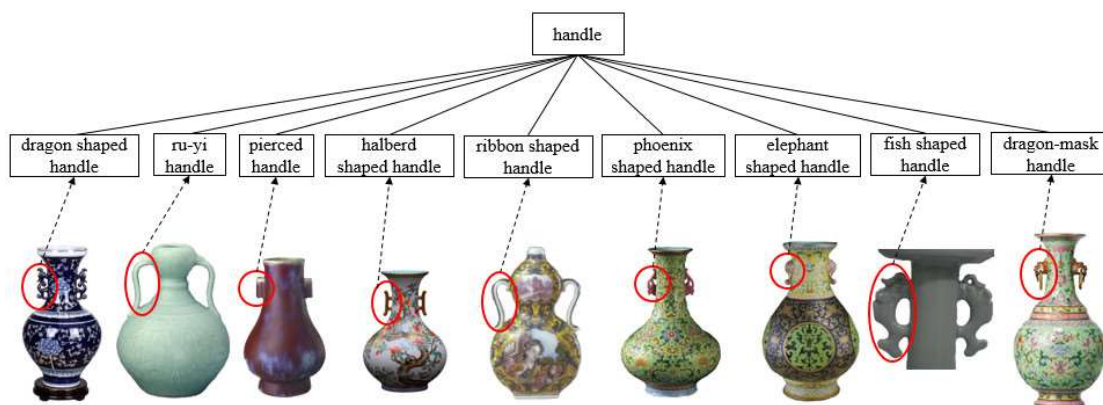


Figure 4 : Les différents types de anses

5.1.2 Analyse morphologique des expressions et termes chinois

Les caractères qui composent les termes chinois et les expressions désignant des vases particuliers sont, dans une approche « atomiste » de la signification, porteurs de sens en lien avec les objets qu'ils dénotent. Ainsi, le dernier caractère d'un terme correspond au type de vase, les autres caractères, appelés « modificateurs », en précisent les caractéristiques qu'elles soient essentielles telles que la forme, la matière, les éléments structurels, ou descriptives telles que la couleur ou la dynastie. Par exemple, l'expression “清

¹⁶⁵ Afin de clairement distinguer les dimensions linguistique et conceptuelle, nous adopterons les conventions d'écriture introduites par l'ontoterminologie [Roche 2007] : les noms de concept commencent par une majuscule et seront notés entre chevrons, par exemple <Vase with long neck with pierced handles without lid without ring>, et les termes en minuscules entre guillemets, par exemple "arrow vase", les caractéristiques essentielles entre barres obliques, par exemple /with long neck/, /with pierced handles/.

雍正 粉青釉 凸花 如意耳 蒜头 瓷 瓶”¹⁶⁶ véhicule les caractéristiques descriptives relatives à la dynastie (“清” dynastie Qing), l’empereur (“雍正” Yongzheng), la couleur du vernis (“粉青釉” vernis de couleur bleue), et le type de décoration (“凸花” fleurs). Elle véhicule également les caractéristiques essentielles portant sur le type de anses (“如意耳” Ru-Yi handle), de forme (“蒜头” en forme de tête d’ail), de matériau (“瓷” porcelaine). Enfin le dernier caractère indique le type de récipient (“瓶” vase).

5.2 Combinaison de caractéristiques essentielles

Si un concept est défini par une combinaison unique de caractéristiques [ISO 1087], toute combinaison valide¹⁶⁷ de caractéristiques ne définit pas pour autant un concept porteur de sens pour les experts du domaine. Nous considérerons ici qu’un concept est un ensemble de caractéristiques suffisamment stable pour être nommé en langue. Notons néanmoins que des concepts sans désignation peuvent être introduits à des fins d’organisation du système conceptuel, par exemple le concept de vase à une seule bouche. Les termes constituent donc un fil conducteur pour la construction des concepts. Ainsi, le terme “蒜头瓶”, “garlic vase” en anglais, désigne l’ensemble des caractéristiques essentielles suivant : {/vase/, /one mouth/, /garlic-shape mouth/, /ring foot/}. Sur la base de cette définition formelle, on proposera la définition en langue naturelle “Vase with a garlic-shape mouth and a ring foot”. Nous pouvons remarquer que les caractères “圈足” (“ring foot”) n’apparaissent pas dans le terme, une ellipse qui s’explique en partie par le fait que tous les types de Garlic vase (Garlic vase I et Garlic vase II) possède un pied en forme d’anneau.

5.3 Caractéristiques descriptives

Les caractéristiques descriptives décrivent l’état dans lequel se trouve un objet. En l’occurrence, l’empereur, et donc la dynastie, sous lesquels a été fabriqué le vase, le four dans lequel il a été cuit, la couleur de son vernis, sa hauteur, etc. Contrairement aux caractéristiques essentielles, elles possèdent une valeur. Elles ne participent pas directement à la définition du concept : on distingue ici définition du concept et description de l’objet.

6. Implémentation

6.1. Protégé

La construction de l’ontologie a été faite à l’aide de Protégé¹⁶⁸, l’environnement le plus utilisé pour la construction d’ontologies au format du W3C (RDF/OWL). Il fournit de nombreux outils et fonctionnalités : interfaces graphiques, inférences de propriétés, vérification de cohérence (consistance), etc. Libre de droits, il bénéficie d’une communauté importante d’utilisateurs qui participent à son développement et sa diffusion. Protégé repose sur une logique de description [Baader et al. 2003], c’est-à-dire qu’on s’intéresse ici à des individus (objets) liés entre eux par des descriptions (relations binaires) : un individu prend « sens » non pas par ce qu’il *est*, mais à travers les relations qu’il entretient avec les autres individus. Les individus se

¹⁶⁶ Afin d’aider à la lecture les « modifieurs » sont séparés par des espaces.

¹⁶⁷ Au sens où cette combinaison ne contient pas de caractéristiques opposées, /avec anses/ et /sans anses/ par exemple

¹⁶⁸ <https://protege.stanford.edu/>

regroupent en classes¹⁶⁹, qui elles-mêmes se structurent en une hiérarchie selon la relation ensembliste d'inclusion.

6.2 Traduction de l'ontologie en OWL

Les objets (vases) sont représentés comme des individus et les concepts comme des classes nommées (figure 5). La notion de relation correspond à celle de propriété entre objets ('object property'). L'ontologie Tao Ci compte 10 caractéristiques descriptives. Elles sont représentées soit sous la forme de propriétés entre objets, par exemple pour l'empereur, soit sous la forme d'une propriété liant un objet à une donnée ('data property') comme la hauteur.

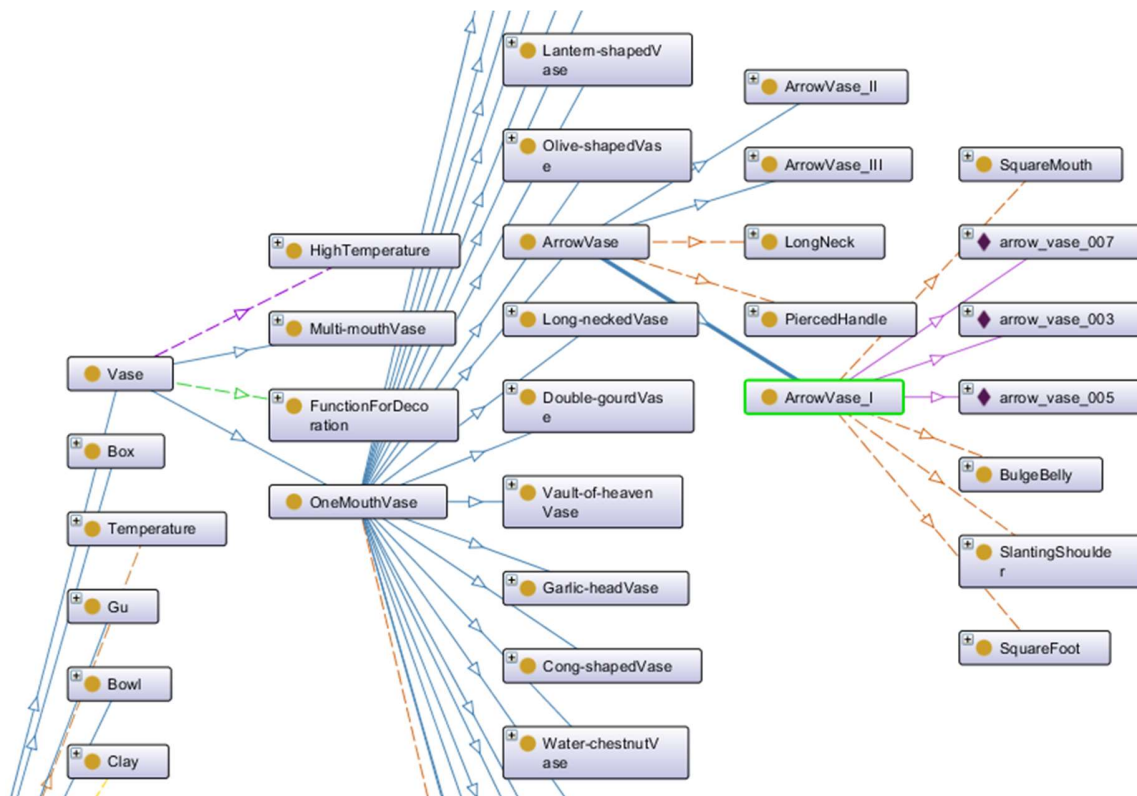


Figure 5 : La des vases et la classe ArrowVase_I

La notion de caractéristique essentielle n'existant pas en Logique de Description – elle correspond à la notion de prédicat rigide¹⁷⁰ et relève d'une logique d'ordre supérieur – il a fallu la traduire en Protégé. Nous avons décidé de représenter les caractéristiques essentielles sous la forme de classes nommées¹⁷¹. Ainsi, les caractéristiques essentielles correspondant aux différentes parties d'un vase ont été traduites sous la forme de sous-classes de la classe Component : Lid class, Mouth class, Neck class, Handle, Shoulder, Belly, Foot, etc. Certaines de ces sous-classes se subdivisant elles-mêmes en classes plus spécifiques : LongNeck class et ShortNeck class sont des sous-classes de la classe Neck, RingFoot et SquareFoot sous-classes de Foot,

¹⁶⁹ "A class defines a group of individuals that belong together because they share some properties" [OWL 2012]

¹⁷⁰ Un prédicat rigide est un prédicat vrai dans tous les mondes possibles [Guarino et al. 1994]

¹⁷¹ Il existe d'autres représentations possibles, dont une sous la forme d'individus.

etc. Il en est de même en ce qui concerne les caractéristiques essentielles correspondant aux fonctions, telles que */for decoration/*, représentées comme sous-classes de la classe *Function*.

La possession d'une caractéristique essentielle pour un concept est représentée comme une restriction de propriété dont le co-domaine correspond à la caractéristique essentielle. Ainsi, posséder une caractéristique essentielle, par exemple */long neck/*, c'est être une sous-classe de la classe anonyme définie par la restriction de la propriété 'has_component' sur la classe *LongNeck*, restriction définie par : 'has_component *some LongNeck*'. De même, être une sous-classe de la restriction de la propriété 'has_function', par exemple 'has_function *some FunctionForDecoration*', traduira le fait de posséder la caractéristique essentielle */for decoration/*.

Toutes les caractéristiques essentielles ne peuvent pas être représentées sous la forme d'une classe. C'est le cas de */without lid/* et */without ring/*. Posséder une telle caractéristique s'exprimera alors sous la forme d'une négation exprimant l'impossibilité d'une relation, par exemple : 'not (has_component *some Lid*)'.

Ainsi, la classe des 'Arrow vase' est formellement définie comme l'ensemble des vases liés à un individu de la classe *LongNeck*, à deux individus de la classe *PiercedHandle*, à un individu de la classe *FunctionForDecoration*, à aucun individu de la class *Lid*, etc. Cette définition formelle n'implique en rien l'obligation aux classes *LongNeck*, *PiercedHandle* et *FunctionForDecoration* de posséder des individus (figure 6).

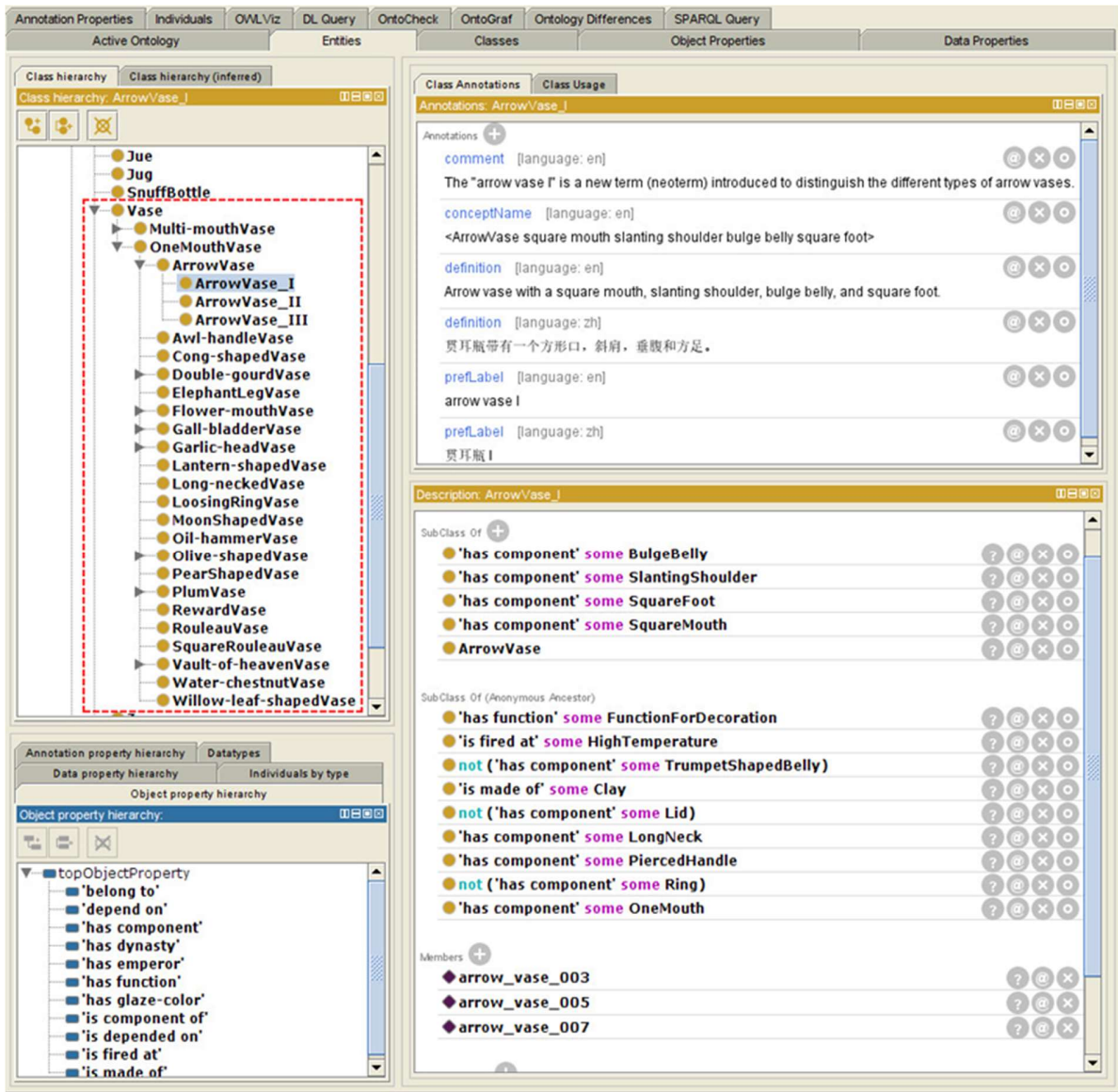


Figure 6 : L'ontologie Tao Ci sous Protégé

Notons que la traduction d'une ontologie construite sur la notion de caractéristique essentielle en une ontologie basée sur une logique de description n'est pas une démarche naturelle pour les experts : "As the group that developed Protégé, the most widely used ontology editor, we are keenly aware of how difficult the users perceive this task to be" [Horridge et al. 2013], "The meaning of terms that denote cultural objects is based on knowledge of the field and more specifically on the way in which experts classify, organize and structure the objects of the world." [Roche & Papadopoulou 2019].

6.3 Intégration

L'intégration de ressources existantes est un point important, elle permet non seulement de compléter l'ontologie, mais aussi de la lier et de l'aligner sur des ontologies de référence. Pour la dimension

conceptuelle, l'ontologie Tao Ci est alignée avec CIDOC CRM¹⁷² (classes E4_Period, E21_Person, E22_Man-Made_Object, E57_Material). Pour cela nous avons utilisé le vocabulaire SKOS pour annoter les concepts (*skos:exactMatch*, *skos:broadMatch*). Par exemple la classe Vessel est liée par la propriété *skos:broadMatch* avec la classe 'E22 Man-Made Object' de CIDOC CRM (figure 7).

E22 Man-Made Object in Version 6.1

Subclass of : E19 Physical Object, E24 Physical Man-Made Thing
Superclass of: E84 Information Carrier

Scope Note:
This class comprises physical objects purposely created by human activity.

No assumptions are made as to the extent of modification required to justify regarding an object as man-made. For example, an inscribed piece of rock or a preserved butterfly are both regarded as instances of E22 Man-Made Object.

Examples:


- Mallard (the World's fastest steam engine)
- the Portland Vase
- the Coliseum

Figure 7. La classe « E22 Man-Made Object » de CIDOC CRM
(<http://www.cidoc-crm.org/Entity/e22-man-made-object/version-6.1>)

Tao Ci est également liée avec le thésaurus AAT de la fondation Getty (Art & Architecture Thesaurus). Pour cela nous avons utilisé le vocabulaire RDFS. Par exemple, la classe Vase est liée par la propriété *rdfs:seeAlso* au concept Vase de AAT (figure 8).

¹⁷² <http://www.cidoc-crm.org/cidoc-crm/>

ID: 300132254 Record Type: [concept](#)
Page Link: <http://vocab.getty.edu/page/aat/300132254>

 **vases** (vessels (containers), <containers by form>, ... Furnishings and Equipment (hierarchy name))

Note: Vessels of varying shape and size but which are usually taller than they are wide, varying greatly in actual form and use. In modern usage, typically refers to vessels for displaying flowers. When referring to ancient art, often refers to any ceramic or metal vessel in a range of shapes and used to hold liquids, grain, or another substance.

Terms:

- vases ([preferred](#), [C,U,LC,English-P,D,U,PN](#))
[\(French-P,D,U,PN\)](#)
- vase ([C,U,English,AD,U,SN](#))
[\(French,AD,U,SN\)](#)
- 花瓶 ([C,U,Chinese \(traditional\)-P,D,U,U](#))
- 陶瓶 ([C,U,Chinese \(traditional\),UF,U,U](#))
- huā píng ([C,U,Chinese \(transliterated Hanyu Pinyin\)-P,UF,U,U](#))
- hua píng ([C,U,Chinese \(transliterated Pinyin without tones\)-P,UF,U,U](#))
- hua p'ing ([C,U,Chinese \(transliterated Wade-Giles\)-P,UF,U,U](#))
- vazen ([C,U,Dutch-P,D,U,U](#))
- vaas ([C,U,Dutch,AD,U,U](#))
- vasi ([C,U,Italian,D,U,PN](#))
- vaso ([C,U,Italian-P,AD,U,SN](#))
[\(Spanish,AD,U,SN\)](#)
- vasos ([C,U,Spanish-P,D,U,PN](#))
- vaso florero ([C,U,Spanish,AD,U,SN](#))
- florero ([C,U,Spanish,UF,U,SN](#))

Figure 8. Le concept Vase de AAT (<http://vocab.getty.edu/page/aat/300132254>)

Enfin, les objets (vases) de Tao Ci sont liés par la propriété `rdfs:seeAlso` avec les vases correspondant provenant des différents musées et le cas échéant avec leurs images lorsqu'elles existent (propriété `foaf:depiction`).

6.4 Dimension terminologique

La dimension terminologique a été réduite, comme c'est souvent le cas, à des annotations sur les concepts à l'aide des vocabulaire RDFS et SKOS : `skos:prefLabel` pour les termes, `skos:definition` pour leur définition en langue naturelle calquée sur la définition formelle des concepts dont ils sont les désignations, etc. (figure 9).



The screenshot shows a hierarchical tree on the left with 'ArrowVase_I' selected. The right pane shows the following annotations:

- `skos:prefLabel` [language: en] arrow vase I
- `skos:prefLabel` [language: zh] 贯耳瓶 I
- `skos:definition` [language: en] Arrow vase with a square mouth, slanting shoulder, bulge belly, and square foot.
- `skos:definition` [language: zh] 贯耳瓶带有一个方形口，斜肩，垂腹和方足。
- `rdfs:comment` [language: en] The "arrow vase I" is a new term (neoterm) introduced to distinguish the different types of arrow vases.
- `conceptName` [language: en] <ArrowVase square mouth slanting shoulder bulge belly square foot>

Figure 9. Annotations de la classe ArrowVase_I

Il est à souligner que nous avons été amenés à introduire de nouveaux termes (néologismes). En effet, la construction de l'ontologie Tao Ci nous a conduit à distinguer de façon plus précise certains vases qui, s'ils partageaient certaines caractéristiques communes, s'en distinguaient par d'autres. Ainsi, afin de distinguer les différents types de "garlic-head vase" (蒜头瓶), nous avons défini trois nouveaux concepts (classes) et trois nouveaux termes les désignant : "arrow vase I" ("贯耳瓶 I"), "arrow vase II" ("贯耳瓶 II"), "arrow vase III" ("贯耳瓶 III") (figure 9).

6. 5 Disponibilité

L'implémentation de l'ontologie Tao Ci en OWL a nécessité la création de 165 classes, 11 propriétés entre objets, 8 propriétés entre objets et données, 132 objets (vase) et 3124 axiomes.

Elle peut être consultée à partir du site web <http://www.dh.ketrc.com/OTC/index.html> et est en accès libre au format OWL à l'adresse : <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl>

La dernière phase du projet a consisté à réaliser un site web dédié <http://www.dh.ketrc.com> (figure 10). Ce site donne accès aux différentes ressources du projet et en particulier à un dictionnaire électronique bilingue (anglais, chinois) des vases des dynasties Ming et Qing. Les entrées de ce dictionnaire correspondent aux classes OWL de l'ontologie. Ce site permet également de consulter les différents objets (vases) associés à l'ontologie (figure 11).



TAO CI Project

The TAO CI Project is a collaborative project dedicated to defining the concept denoted by Chinese ceramics vessel terms. The purpose of TAO CI project is to provide a model of publishing open data for museum and link data of the Chinese ceramics and build a multi-linguistics e-dictionary of Chinese ceramics to communicate with archeologists in the world.

The TAO CI project is based on the ISO 704 and ISO 1087 to develop this model. It is an interdisciplinary project, which is related to Archeology (Cultural Heritage), Linguistic (Terminology), Artificial Intelligence (Knowledge Representation), Semantic Web (Linked Data). The methodology of the TAO CI project is the ontoterminology that is a terminology whose conceptual system is a formal ontology.

Support



China Scholarship Council

The TAO CI project was funded by China Scholarship Council from November 2017 to November 2020.

Figure 10. Le site web de Tao Ci (<http://www.dh.ketrc.com>)

7. Evaluation

La dernière phase de construction d'une ontologie est son évaluation afin de "to assess the quality and correctness of the obtained ontology" [Sabou & Fernandez, 2012]. Cette évaluation peut porter sur différents aspects de l'ontologie : son implémentation informatique, sa capacité à répondre aux questions de compétences et sa couverture du domaine en termes de classification des objets.

Nous avons soumis notre ontologie à l'outil OOPS!¹⁷³, un outil en ligne pour détecter certains des pièges les plus courants apparaissant lors du développement d'ontologies [Poveda-Villalón et al., 2014]. OOPS! n'a détecté que des pièges considérés comme mineurs. Par exemple, P08 "Annotations manquantes" et P13 "Relations inverses non explicitement déclarées".

¹⁷³ <http://oops.linkeddata.es/>

Nous l'avons également soumis à OntoMetrics¹⁷⁴, une plateforme en ligne pour le calcul de statistiques [Lantow, 2016]. Le tableau 2 présente quelques résultats de mesure de la « richesse » de l'ontologie [Denny, 2010].

Metric	Value
Attribute richness ¹⁷⁵	0.048485
Inheritance richness ¹⁷⁶	2.715152
Relationship richness	0.334324
Class/Relation ratio	0.245171
Average population	0.8
Class richness	0.321212

Table 2. Résultats de l'évaluation par OntoMetrics

La plupart des scores sont très faibles. Cela est dû à la représentation en OWL des caractéristiques essentielles traduites sous la forme de classes sans aucun attribut (richesse des attributs). L'évaluation des critères dépend fortement des objectifs de l'ontologie et des choix faits quant à sa mise en œuvre : "a good ontology does not perform equally well with regards to all criteria" [Denny, 2009]. L'objectif principal de l'ontologie Tao Ci est la classification des vases et non la représentation de relations horizontale entre les vases et d'autres artefacts (richesse des relations, rapport classe/relation), ni le peuplement de l'ontologie (population moyenne, richesse des classes).

Nous avons ensuite évalué notre ontologie au regard des questions de compétences établies au début de notre projet. Les questions de compétences ont été traduites en requêtes SPARQL pour l'interrogation de l'ontologie Tao Ci au format RDF/OWL. Elles ont toutes été satisfaites. Prenons pour exemple les questions de compétences 6 et 12 (table 1) :

QC 6 : « Quels sont les termes anglais et chinois désignant les vases ? » se traduit en SPARQL par :

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX otc: <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#>
SELECT ?english_name ?chinese_name
WHERE {
  ?vase rdfs:subClassOf* otc:Vase.
```

¹⁷⁴ <https://ontometrics.informatik.uni-rostock.de/ontologymetrics/>

¹⁷⁵ "The attribute richness (AR) is defined as the average number of attributes (slots) per class. It is computed as the number attributes for all classes (ATT) divided by the number of classes (C): $AR = \frac{ATT}{C}$." https://ontometrics.informatik.uni-rostock.de/wiki/index.php/Schema_Metrics

¹⁷⁶ "This metric reflects the diversity of the types of relations in the ontology. The relationship richness (RR) of a schema is defined as the ratio of the number of (non-inheritance) relationships (P), divided by the total number of relationships defined in the schema (the sum of the number of inheritance relationships (H) and non-inheritance relationships (P))." https://ontometrics.informatik.uni-rostock.de/wiki/index.php/Schema_Metrics#Inheritance_Richness

```

?vase skos:prefLabel ?english_name.
?vase skos:prefLabel ?chinese_name.
FILTER (lang (?english_name)='en')
FILTER (lang (?chinese_name)='zh')
}
ORDER BY ?english_name

```

QC 12 : « Quels sont les vases produits sous la Dynastie Qing ? » se traduit en SPARQL par :

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX otc: <http://www.dh.ketrc.com/otcontainer/data/OTContainer.owl#>
SELECT DISTINCT ?vase_dynasty_Qing
WHERE {
?vase_dynasty_Qing rdf:type owl:NamedIndividual.
?vase_dynasty_Qing otc:hasDynasty otc:Qing
}
ORDER BY ?vase_dynasty_Qing

```

Le tableau 3 liste les premiers résultats pour chacune de ces questions.

english_name	chinese_name	vase_dynasty_Qing
"arrow vase"@en	"贯耳瓶"@zh	arrow_vase_001
"arrow vase I"@en	"贯耳瓶 I"@zh	arrow_vase_002
"arrow vase II"@en	"贯耳瓶 II"@zh	arrow_vase_003
"arrow vase III"@en	"贯耳瓶 III"@zh	arrow_vase_004
"awl-handle vase"@en	"锤把瓶"@zh	arrow_vase_005
"cong-shaped vase"@en	"琮式瓶"@zh	arrow_vase_006
"double-gourd vase"@en	"葫芦瓶"@zh	arrow_vase_007
"double-gourd vase I"@en	"葫芦瓶 I"@zh	arrow_vase_008
"double-gourd vase II"@en	"葫芦瓶 II"@zh	awl-handle-shaped_vase_001
"double-gourd vase III"@en	"葫芦瓶 III"@zh	cong-shaped_vase_001
"double-tube vase"@en	"多管瓶"@zh	cong-shaped_vase_002
"elephant leg vase"@en	"象腿瓶"@zh	cong-shaped_vase_003
"flower-mouth vase"@en	"花口瓶"@zh	double-gourd_vase_003
"flower-mouth vase I"@en	"花口瓶 I"@zh	double-gourd_vase_004
"flower-mouth vase II"@en	"花口瓶 II"@zh	double-gourd_vase_005
		double-gourd_vase_006

Table 3. Réponses aux questions de compétences QC6 et QC12

Enfin, au regard de nos objectifs de classification et de terminologie, l'ontologie Tao Ci couvre bien le domaine au sens où chaque individu relève clairement d'un concept (classification), et où chaque concept est clairement défini comme une combinaison unique de caractéristiques essentielles permettant la définition aristotélicienne de termes en langue naturelle calquée sur la définition formelle du concept.

Description of arrow vase 002

owl:Class Arrow Vase III

diameter of foot 18

is collected in THE PALACE MUSEUM

number of mouth 1

prefLabel blue-and-white arrow vase painted with lotus flowers, Qianlong mark of Qing dynasty

is decorated by lotus flowers pattern

height 55

diameter of mouth 11

prefLabel 清乾隆青花荷莲纹贯耳瓶

has emperor Qianlong

has dynasty Qing

has glaze-color blue-and-white

is made of clay

depiction <https://www.dpm.org.cn/Uploads/Picture/dc/57102.jpg>



Figure 11. Un exemple de Arrow vase III

8. Conclusion

A travers le projet Tao Ci nous avons pu montrer l'intérêt de l'Ontologie et de la Terminologie pour la préservation du Patrimoine Culturel et sa diffusion dans un format numérique compatible avec les données ouvertes et liées (Linked Open Data).

Dans le cadre de notre travail nous nous sommes intéressés aux vases en céramique chinois des dynasties Ming (1368-1644) et Qing (1644-1911) dont il existe de nombreuses collections réparties dans différents musées en Chine, rarement accessibles dans un format ouvert.

Le résultat est double. C'est d'abord la construction de la première ontologie au format du W3C de la céramique chinoise des dynasties Ming et Qing. Ce fut ensuite la réalisation d'un dictionnaire électronique bilingue (chinois-anglais) des vases basé sur l'ontologie de domaine.

Nous avons adopté pour la construction de cette ontologie et de cette terminologie, une méthode guidée par les termes et les caractéristiques essentielles afin de tenir compte de la façon de travailler des experts et des

principes terminologiques des normes ISO. Méthode que nous pouvons résumer en remarquant qu'un concept est un ensemble de caractéristiques suffisamment stable pour être nommé en langue. Les termes servent alors de fil conducteur dans la construction de l'ontologie. L'identification des caractéristiques essentielles, à partir desquelles se définissent les concepts, repose sur la recherche de différences entre objets (vases), tant fonctionnelles que structurelles, et sur une analyse morphologique des termes chinois, les caractères les composant étant porteurs de sens au regard des connaissances du domaine (approche « atomiste » de la signification).

La construction de l'ontologie a permis d'introduire de nouveaux termes (néologismes). En effet, elle a nous a conduit à distinguer de façon plus précise certains vases qui, s'ils partageaient certaines caractéristiques communes, s'en distinguaient par d'autres. Il devenait alors intéressant de pouvoir les nommer.

L'implémentation en Protégé de l'ontologie Tao Ci a soulevé le problème de la traduction en OWL des caractéristiques essentielles, cette notion n'existant pas en logique de description, et de leur combinaison pour aboutir à la définition de classes. Si le résultat est satisfaisant d'un point de vue formel, elle confirme le fait que l'utilisation d'un tel environnement peut difficilement se faire par les experts sans l'aide d'un ingénieur cognitif.

L'ontologie et le dictionnaire bilingue sont accessibles à partir du site <http://www.dh.ketrc.com/>.

Les travaux futurs seront menés dans deux directions différentes. La première consiste à enrichir la dimension linguistique. Actuellement, les termes sont réduits à des étiquettes sur les classes, certains vocabulaires comme OntoLex-Lemon permettraient de représenter la dimension linguistique de façon plus satisfaisante. La seconde vise d'une part à compléter l'ontologie Tao Ci en prenant en compte d'autres types de récipients en céramique et d'autre part, en lien le projet Lekythos sur la poterie de la Grèce antique mené au sein de notre laboratoire, à développer une « core » ontologie des vases.