

# Modeling Ontologies for Individual Artists: A Case Study of a Dutch Ceramic Glass Sculptor

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Most Cultural Heritage information currently available in the form of structured knowledge representations is limited to aggregated information extracted from general collection management systems and archives. These predominantly describe collections and artefacts at a general level. However, individual artists are able to provide information at a much higher level of variety and detail. This paper investigates the usefulness of ontologies to structuring and providing access to enriched information related to individual artists and their works. It reports on a case study developing and validating an ontology for a ceramic glass artist. The study follows the Methontology ontology engineering methodology. Ontology development is validated using domain-specific competency questions related to artworks and production processes. The case study shows how ontologies may be used to structure enriched information pertinent to works of individual artists. Ontologies provide access to such information, including details on activities related to creative and productive processes of artworks. Moreover, information may encompass materials processed, equipment used, locations, time spans, parties involved, and chronological and causal registration of how activities take place. Modeling information this way may further facilitate both experts’ as well as the general public’s access to information.

**Keywords:** ontology engineering; cultural heritage; methontology

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# 1 Introduction

There is a long tradition of using structured, machine interoperable knowledge using semantic technologies in the Cultural Heritage domain (Hyvönen, 2012), allowing experts to access and interpret Cultural Heritage information by means of intelligent reasoning and inferencing. As noted by Amin et al. (2008), Cultural Heritage experts have rather different information needs, ranging from handling information related to specific objects and (potential) collections, unconstrained intelligence for prospective publications to the construction of structured vocabularies for museums, archives, and libraries. Experts search for information in ‘analog’ literature and archives and use search engines to find information in collection management systems and digital sources.

Currently, most information on the (creation of) artworks that is available in the form of structured knowledge representations, such as Linked Data, is limited to the aggregated information stored in general collection management systems such as Europeana<sup>1</sup>, the Getty Research Institute<sup>2</sup>, RKDartists<sup>3</sup>, and digital archives of museums. While several papers have been published related to the design of ontologies for Cultural Heritage institutions, there has been no detailed investigation of the use of ontologies to specify information related to the works of individual artists and the development of such ontologies. Artists dispose of detailed, pertinent, and significant information on (concepts related to) production materials, methods, and techniques as well as on creative and constructive processes. Such information cannot be specified in great detail using the current solutions.

While several papers are published on designing ontologies for Cultural Heritage institutions, there are as yet no detailed investigations into the use of ontologies to specify information relative to the work of individual artists and the systematic development of such ontologies. This paper investigates knowledge representations for modeling Cultural Heritage information at a high level of variety and detail as can be provided by individual artists. Special focus is on documenting artists’ collections to better facilitate experts’ search tasks (Munir and Anjum, 2018).

What follows describes the emergence of a formal ontology (Gruber, 1995) modeling specific information for individual artists. This includes developing and validating art-specific concepts and requirements. The paper presents a reusable method, building on the ‘Methontology’ method for ontology development (Fernández-López et al., 1997), describing the steps of specification, conceptualization, integration, implementation, and evaluation in a case study on a contemporary ceramic glass sculptor.

The aim is to create a machine-processable structure for information related to artworks and artist (Dijkshoorn et al., 2018). Documenting the artists’ collection in this structure, in turn, enables improved query construction, thereby increasing the information retrieval capabilities of Cultural Heritage experts (Munir and Anjum, 2018).

Defining concepts related to individual artists and their work also opens up possible linkages of these concepts and a variety of other data sources. Currently, efforts are being made within the Cultural Heritage domain attempting to improve Linked Data practices describing art. An example of these efforts is the Linked Art initiative in which several institutions and museums cooperatively develop a shared data model with

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<sup>1</sup> <https://www.europeana.eu/>

<sup>2</sup> <https://www.getty.edu/research/>

<sup>3</sup> <https://rkd.nl/nl/explore/artists>

links to the terminology of Getty Vocabularies<sup>4</sup>. A second example is an initiative of the Dutch organization Network Digitaal Erfgoed (NDE) in collaboration with CLARIAH, named Termennetwerk<sup>5</sup>. Termennetwerk provides access to various terminology sources such as the Getty Art and Architecture Thesaurus (AAT), Dutch heritage thesauri published by national aggregators (RCE, SVCN), and geographical thesauri such as GeoNames and WikiData.

Accessing and reusing shared vocabularies plays a vital role in creating semantic connections between (descriptions of) artworks and related concepts. Therefore, the focus is on linking concepts to the terminology of shared vocabularies too. There is a need for this new kind of representations as current solutions are limited to structuring general information only, while artists themselves are very well able to provide information at a much higher level of detail and variety.

## 1.1 Case Study

The case study involves modeling an ontology specifying information related to the work of the Dutch ceramic glass sculptor Barbara Nanning<sup>6</sup>. After graduating from the Gerrit Rietveld Academy forty years ago, she is now viewed as a well-respected artist by both national and international institutions (Eliëns, 2019). While she originally majored in ceramics, she has later shifted her focus to exclusively creating artwork made of glass.

Glass art can have particularly varying and complex creation processes. Production may require glass techniques such as ‘casting’, ‘fusing’, and ‘slumping’. In the case of the artist, there also is a geographical division between activities related to conceiving, pattern building, and preparing in the Netherlands and creation and finishing of the work itself in the Czech Republic (Eliëns, 2019). Capturing and structuring this variation and complexity in an ontology is challenging. Moreover, as there are no structured data sources available for most of the information sought, deriving this information requires several intensive knowledge acquisition trajectories.

This paper describes the application of an existing ontology engineering methodology to develop a knowledge representation specifying and providing access to enriched information related to the works of the artist. This ontology is validated and evaluated to assess the extent to which the case study can be generalized to artists in general.

The remaining part of this paper is structured as follows: Section 2 provides an overview of related work. Section 3 describes the development of the ontology and its results. Section 4 discusses the evaluation of (the potential usage of) the ontology. Section 5 presents discussion, conclusion, and directions for future research.

## 2 Context

### 2.1 Cultural Heritage modelling

The engineering of ontologies is a core research topic within the semantic web community (Pattueli, 2011). Over the last several decades, efforts have led to the development of ontologies within different domains (Iqbal et al., 2013), among which Cultural Heritage. Some domain ontologies are widely accepted and, though they make use of

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<sup>4</sup> <https://linked.art/index.html>; <http://vocab.getty.edu/>

<sup>5</sup> <http://demo.netwerkdigitaalerfgoed.nl/termennetwerk/en>

<sup>6</sup> <http://www.barbarananning.nl/>

different approaches, are generally able to describe artworks and collections (Dijkshoorn et al., 2018). One of these is the CIDOC-CRM ontology, developed for Cultural Heritage institutions to facilitate information integration (Doerr, 2003). CIDOC-CRM maintains an event-centric approach to describing artworks and the provenance of artworks. An example of an event would be the acquisition event or “E8:Acquisition” indicating a change in ownership. Events are connected to artworks by means of object properties<sup>7</sup>. CIDOC-CRM is developed specifically for use by institutions publishing collection metadata, including “museums, libraries and archives”<sup>8</sup>, with its goal being the achieving of interoperability of collection metadata (Dijkshoorn et al., 2018).

Another widely adopted ontology is the Europeana Data Model (EDM), created to enable structured data delivery to Europeana by cultural heritage institutions (Doerr et al., 2010). EDM also maintains an object-centric approach, describing artworks using a collection of object properties<sup>9</sup>. Like CIDOC-CRM, EDM is designed both specifically for the museum sector at a high level of aggregation. It is designed as a more general interoperability layer on top of more specific models (Dijkshoorn et al., 2018).

Whilst these ontologies focus on structuring general information related to the collections of Cultural Heritage organizations on a general level, they are not designed to structure information related to works of individual artists at a high level of detail. This study investigates the bottom-up development of such a more specific ontology as well as to what extent the resulting ontology can be mapped to CIDOC and EDM.

## 2.2 Ontology Engineering Methodology

For the case study, an ontology engineering methodology is used, introduced by Fernández-López et al. (1997) named ‘Methontology’. This is further described in Section 3.

Methontology appears in several publications presenting ontologies for different domains using the Methontology methodology. One of these is the ITEMAS ontology, as presented by Moreno-Conde et al. (2019), having its origins in the healthcare domain. The main domain concepts relate to public healthcare organizations and health technology innovations. In Kalbasi et al. (2014), a minimalist ontology is developed in the domain of geosciences to stimulate collaborative ontology development. Other ontologies include one presented by Hennig et al. used for annotating and comparing cytometric (cell measurement) data and one chemical ontology published as a best practice example of Methontology itself by Fernández et al. (Hennig et al., 2009; López et al., 1999). Several of the involved ontology engineers indicate having chosen Methontology because of the highly detailed documentation and examples available.

Some papers also refer to using an adapted version of Methontology or a mixture of several ontologies including Methontology. An ontology for Greek mythology defined by Syamili and Rekha makes use of three different ontology engineering approaches (Syamili and Rekha, 2018). Among these Methontology, from which the development stages are adopted, yet without, among other things, the evaluation stage. Finally, there is an ontology for specifying cultural heritage resources based on Methontology (Pattueli, 2011). This ontology prototype is refined using a different methodology in the later stages of the project.

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<sup>7</sup> [http://www.cidoc-crm.org/sites/default/files/cidoc\\_crm\\_version\\_5.0.4.pdf](http://www.cidoc-crm.org/sites/default/files/cidoc_crm_version_5.0.4.pdf)

<sup>8</sup> <https://www.cidoc-crm.org/>

<sup>9</sup> [https://pro.europeana.eu/files/Europeana\\_Professional/Share\\_your\\_data/](https://pro.europeana.eu/files/Europeana_Professional/Share_your_data/)

## 2.3 Methontology

Over the last decades, several methodologies for ontology engineering have been defined, providing descriptions of techniques and activities that come with developing ontologies (Iqbal et al., 2013). Nevertheless, analysis by Iqbal et al. suggests a lack of mature methodologies (Iqbal et al., 2013). This is mainly caused by poor documentation related to techniques and activities being insufficiently detailed. Contrary to this, Methontology (Fernández-López et al., 1997) provides a methodology whose documentation contains a high level of details.

Methontology bases the development of ontologies on the concept of an ‘evolving prototype’ in which ontologies pass through well-documented stages of specification, conceptualization, integration, implementation, and evaluation (Fernández-López et al., 1997). The concept of an evolving prototype makes that definitions can be refined or complemented when necessary based on constructed user stories.

Given that the requirements of an ontology are not clear initially, the adoption of an evolving prototype approach is advisable as it can be used to develop application-independent ontologies (Iqbal et al., 2013). Other reasons motivating a choice for applying Methontology are supported for reusing existing ontologies in the implementation phase. This has resulted in the repeated use of Methontology among ontology engineers.

## 3 Development of the Ontology

This paper substantiates how Methontology can be adapted and applied to develop an ontology departing from unstructured information representing a domain. This section describes how the stages of the Methontology methodology are adapted and applied.

### 3.1 Specification

Purpose and requirements follow from a set of user stories, indicating potential use of the ontology, level of granularity required, and beneficiaries from its development. User stories and corresponding competency questions are helpful during specification to maintain alignment with the purpose of the ontology. User stories and competency questions are effective during the evaluation stage as well, as queries can be defined based on competency questions, thus also serving as a validation method for the whole development effort (Baker and Cheung, 2007). Typically, specification yields a partially complete picture of the domain that needs to be concise and consistent (Fernández-López et al., 1997).

#### 3.1.1 User Stories

The purpose and requirements of an initial prototype follow from two user stories and related competency questions (CQ). User stories and competency questions are developed through analysis of domain literature and structured interviews with the artist<sup>10</sup> (Eliëns, 2019). We restrict ourselves to this information rather than interviewing

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<sup>10</sup> An interesting challenge faced during development of the ontology follow from the restrictions placed on conducting face to face knowledge acquisition activities due to COVID-19. Rather than conducting interviews in person, this called for an alternative approach, especially during specification and conceptualization stages. The study therefore chose to work with digital forms, allowing the artist to

other stakeholders, as our aim is to produce an ontology that is a faithful representation of the world-view and internal information organization of the artist herself. Interviews clarify the kind of information the artist is able and willing to provide. An example of such a question is “Is there access to information related to craftsmen participating in the creation process?”.

User stories address sub-collections of the artist: Verre Églomisé<sup>11</sup> and Coloured Shadows<sup>12</sup>, shown in Figures 1 and 2.



Figure 1: Photographs showcasing the process and end result of the Verre Églomisé sub collection

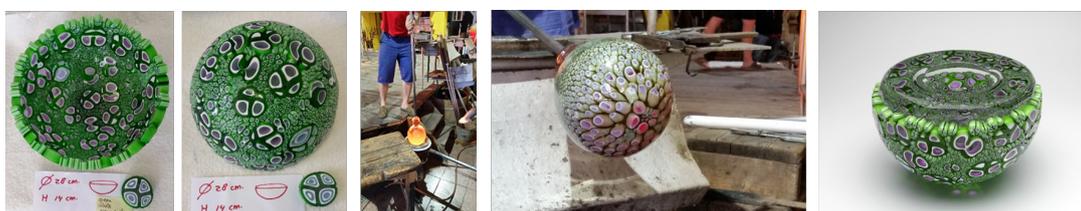


Figure 2: Photographs showcasing the process and end result of the Colored Shadows sub collection

Competency questions typically may then refer to:

- physical dimensions of artworks
- equipment required during creative and productive processes
- skills, crafts, and techniques necessary to achieve targets
- infrastructures, logistics, and locations
- collections, both private and public
- links to general collection management systems and archives

A top-level competency question was identified “As an artist I want to be able to describe artistic and production processes underlying the creation of Verre Églomisé / Coloured Shadows objects as well as to dispose of general information and digital representations of individual artworks, thus improving structuring and managing of documentation.”. For Verre Églomisé (CQ-VE) / Coloured Shadows (CQ-CS), this led to several specific competency questions:

- CQ-VE-1: What are the top two artworks in the Verre Églomisé series sorted by height?

nevertheless purposefully describe artworks and related creative and productive processes.

<sup>11</sup> <https://www.barbarananning.nl/nl/project/verre-eglomise/>

<sup>12</sup> <https://www.barbarananning.nl/project/coloured-shadows/>

- CQ-VE-2: What equipment is used for sandblasting of the artworks within the Verre Églomisé artworks and how can this equipment be described?
- CQ-VE-3: Which artworks in the Verre Églomisé series are currently stored in her private collection?
- CQ-VE-4: What is the description of the technique that was last applied in the creation process of the 'Go with the Flow' artwork from the Verre Églomisé series and which parties were involved in this technique?
- CQ-VE-5: What are the links to the digital representations of the artworks in the Verre Églomisé series?
- CQ-CS-1: What are the top three artworks in the Coloured Shadows series sorted by descending year of completion?
- CQ-CS-2: What activities are part of the creation process of the 'Beneath the Water' artwork in the Coloured Shadows and where have these activities take place?
- CQ-CS-3: What are the materials processed in the creation process of the 'Coral Reef' artwork from the Coloured Shadows collection and during which activities were these materials processed?

Besides competency questions, specific Cultural Heritage data publishing requirements, as identified by Dijkshoorn et al. (2018), are also taken into account. Here, the top-level question is: "As an artist, I want to be able to publish the enriched data describing my artworks and the corresponding creation process to provide access to cultural heritage experts and the general public and thereby improve current fact-finding practices.". Specific requirements are:

- REQ1: assuring the interoperability of the data model while being able to specialize it
- REQ2: supporting both object and event-based approaches for describing artefacts
- REQ3: providing the ability to specify the changes made to artefacts over time
- REQ4: separating the meta-data and representations of artefacts
- REQ5: allowing the inclusion of multiple views of the same artefacts from different sources
- REQ6: providing the ability to add context to artefacts by including domain-specific information

### 3.1.2 Specification Document

The study involves several knowledge acquisition activities, calling for both structured and unstructured interviews with the artist. Topics addressed cover types of activities conducted during creation processes and materials used.

Domain literature is analyzed to gain a basic understanding of glassblowing, glass houses, and artworks of the artist (Eliëns, 2019).

Table 1: Ontology Requirements Specification Document

<b>Ontology Requirements Specification Document</b>	
Domain	- <i>Cultural Heritage / Arts</i>
Purpose	- <i>Ontology specifying enriched information describing artworks from the Verre Églomisé and Coloured Shadows series and modeling related creative and productive processes.</i> - <i>Providing Cultural Heritage experts access to this information.</i>
Level of Formality	<i>Semi-formal</i>
Scope	- <i>List of artworks: Coral Reef, Go with the Flow ...</i> - <i>List of Materials: Glass, Gold Leaf, Alexandrite Glass, Uranium Glass, AJETO Glass, Iron, Louvre Gold Leaf ...</i> - <i>Tools and Equipment: Furnace, Gilders Tip, Blowpipe, Plate System, Cooling Oven, Sharpening Stone ...</i> - <i>Location-related Concepts: Country, Glass Studio, Museum, City ...</i> - <i>People-related Concepts: Actor, Gilder, Glass Blower, Creator ...</i> - <i>Activities: Glassblowing, Gilding, Modeling, Sawing, Grinding ...</i> - <i>Concepts for the Requirements of Data Publication: Event, Thing, Entity, Digital Image ...</i> - <i>Properties: created-by, located-in, has-height, finishes-with, used-for, involves, part-of, has-duration, followed-by ...</i>
Sources	- <i>Domain Literature: Books by Eliëns and te Duits describing Barbara Nanning (Eliëns, 2019; te Duits, 2003).</i> - <i>Textual Descriptions of the artworks and the general creation process of glass artworks.</i> - <i>Interviews with Barbara Nanning discussing her artworks and related creation processes.</i> - <i>Knowledge acquisition with Barbara Nanning in which a digital form is used to describe her artworks and related creation processes.</i> - <i>Requirements for Data Publication (Moreno-Conde et al., 2019).</i>

This all typically results in a first set of key terms representing the domain. The granularity of terms and concepts forms a basis for the scope of the ontology. This scope may then further be expanded by using a middle-out approach. This approach allows for high accuracy and increases in control over stability and level of details (Uschold and Gruninger, 1996).

Four types of standard forms are filled in with the artist. The first type specifies information on the artworks themselves, including naming, dimensions, hyperlinks to images, and when possible and legally permitted (AVG; law on privacy) current location. The second type specifies activity-specific information on roles and equipment. The third type specifies individuals involved in various creation processes, with their role and organizational status. The fourth type specifies per creation process of an artwork, the chronological and causal execution order of activities, with corresponding time spans, locations, parties involved and materials processed.

Once done, this results in 946 terms and definitions, known as the glossary of terms (Raven, 2020). The 946 terms cover 794 instances, 121 concepts, and 31 relations or attributes.

User stories and glossary of terms together build up the ontology requirement specification document, as shown in Table 1. This document specifies (semi-formally)

domain, purpose, scope (including the granularity of terms and concepts), sources and level of formality of the ontology to be designed.

### 3.2 Conceptualization

A set of concept classification trees is constructed based on concepts from the ontology requirement specification document. This results in hierarchies (or sub-class relations) in the 121 concepts, involving entities such as Actors, Periods, Places, Time spans and Representations (Gómez-Pérez et al., 1996; Raven, 2020). An example of a concept classification tree is shown in Figure 3.

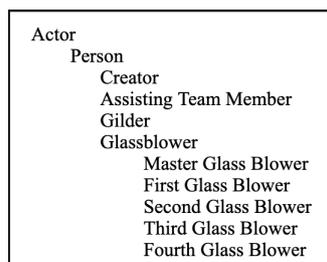


Figure 3: Part of a concept classification tree of the Actor class (indents indicate mutually-disjoint-subclass-of relations)

Based on concept classification trees and glossary of terms a set of data dictionaries, tables of instance attributes, and tables of instances are created (Fernández-López et al., 1997).

Data dictionaries define concepts with related attributes, instances, and relations (Raven, 2020). When constructing data dictionaries, it is important to keep competency questions and requirements in mind, as decisions made compromise information Cultural Heritage experts can query for.

An example of such a decision is not to include concepts related to the fifth requirement defined by Dijkshoorn et al. The support for multiple views may unnecessarily increase complexity when adding concepts like Proxy, View, and Aggregation<sup>13</sup>. Another example is including Creation Events and concepts related to activities part of Creation Events. These concepts allow for structuring information at the level of individual activities, such as materials processed, equipment used, and people involved as shown in Table 2.

Table 2: An example of a data dictionary for the concept Activity with the related relations

Concepts	Instances	Class Attributes	Instance Attributes	Relations
Activity	-	-	-	- Involves - Processes - Requires-Use-Of

Twelve tables are created defining attributes of instances themselves (Raven, 2020). These attributes are all numerical or text-based values (e.g., Has-Name or Has-Depth). An example of such a table is shown in Table 3.

<sup>13</sup> [https://pro.europeana.eu/files/Europeana\\_Professional/Share\\_your\\_data/Technical\\_requirements/EDM\\_Documentation/EDM\\_Mapping\\_Guidelines\\_v2.4\\_102017.pdf](https://pro.europeana.eu/files/Europeana_Professional/Share_your_data/Technical_requirements/EDM_Documentation/EDM_Mapping_Guidelines_v2.4_102017.pdf)

Table 3: An example of an instance attribute table for the attribute Has-Name

<b>Instance Attribute Name</b>	<i>Has-Name</i>
<b>Description</b>	<i>Has-Name is a property which is connected to the name of an entity.</i>
<b>Value Type</b>	<i>String</i>
<b>Unit of Measure</b>	—
<b>Precision</b>	—
<b>Range of Values</b>	—
<b>Default Value</b>	—
<b>Cardinality</b>	<i>1</i>
<b>Inferred from Instance Attribute</b>	<i>Unknown</i>
<b>Inferred from Class Attribute</b>	<i>Unknown</i>
<b>Formula</b>	<i>Unknown</i>
<b>To infer</b>	<i>Unknown</i>
<b>References</b>	<i>Unstructured interviews with the artist discussing her artworks and related creation processes.</i>

A table is defined for each of the 794 instances. These tables define the individual instances by their name, definition, and all relations and attributes with their corresponding values (Raven, 2020). An example of an instance related to New York is shown in Table 4:

Table 4: An example of an instance table for the instance Artwork\_17\_33

<b>Instance Name</b>	<b>Description</b>	<b>Attributes &amp; Relations</b>	<b>Values</b>
New York	New York is a city in the United States of America	<ul style="list-style-type: none"> <li>- Location-Of</li> <li>- Located-In</li> <li>- Has-Name</li> <li>- Is-Described-By</li> </ul>	<ul style="list-style-type: none"> <li>- J. Lohmann Gallery, Artwork_44, Collection J. Lohmann Gallery</li> <li>- United States of America</li> <li>- New York</li> <li>- New York is a city in the United States of America.</li> </ul>

Fernández et al. also recommend including tables of rules, tables of formulas, tables of class attributes, attribute classification trees, and verb diagrams, on which verb dictionaries and table of conditions are based. However terms, concepts, attributes, and relations provide no suitable basis for constructing these representations. Class attributes (as defined in (Raven, 2020)) are attributes describing the class itself rather than its instances. We identify a limited number of class attributes, including disjointness relations between classes (i.e. City and Country). The majority of class attributes however are not class specific but are generic attributes such as class names, class descriptions, that can later be mapped to standard RDF(S)/OWL properties. They are omitted from the table. Other than these, no additional class attributes were identified due to the high level of variance between instances of classes hindering the possibility of including class-wide attributes. Attribute classification trees and verb diagrams provide overviews of composition relations between attributes and between verbs. These representations are unnecessary as they are not present in the current structure. The domain in question also lacks standard formulas and rules which is why no corresponding representations are defined either.

### 3.3 Integration

Methontology supports reusing existing ontologies and vocabularies. The integration phase delivers an integration document stating reused terms from other ontologies or vocabularies and corresponding terms conceptualized in earlier stages.

Main sources reused are terminology sources accessible through Termennetwerk, allowing users to easily connect to sources. This is especially useful during ontology construction.

Analysis of the widely-accepted various domain vocabularies and ontologies yields reusable relations, concepts and terms, resulting in links of 124 reused URIs spread over 7 different terminology sources. Specifically, 5 classes were identified as equivalent to CIDOC-CRM classes (Actor, Period, Timespan, Place and Collection). For these, owl:equivalentClass triples are asserted. Likewise 25 classes indicating more specific artistic processes and roles (“Grinding”, “Glassblowing”, etc.) were mapped to Getty’s AAT. Further mappings were made to Wikidata and the Dutch heritage thesaurus indexed by Termennetwerk.

Concepts that remain unmapped include classes that are even more specific. Some of these are more likely to be reused in other cases (e.g. “Assisting\_Team\_Member”, “Cutting\_Sheets”, “Master\_Glass\_Blower”), where others are likely very specific to the work and process of Nanning (e.g. “Producing\_Coloured\_Canes”, “AJETO\_Glass”).

A further 14 triples linking artworks to landing pages and images are added, to allow for further exploration and visualization of query results.

Table 5 shows a part of the integration document (Raven, 2020).

Table 5: Part of the integration document

Ontology related to the works of Barbara Nanning		
Term in Glossary of Terms	Source to be Reused	URI of the term in the Source
Amsterdam	Geonames	<a href="http://sws.geonames.org/2759794">http://sws.geonames.org/2759794</a>
Artwork	Art & Architecture Thesaurus	<a href="http://vocab.getty.edu/aat/300133025">http://vocab.getty.edu/aat/300133025</a>
Ice Pick	Art & Architecture Thesaurus	<a href="http://vocab.getty.edu/aat/300209549">http://vocab.getty.edu/aat/300209549</a>
Ice Pick	Wikidata	<a href="http://www.wikidata.org/entity/Q586319">http://www.wikidata.org/entity/Q586319</a>
Blowing Pipe	Art & Architecture Thesaurus	<a href="http://vocab.getty.edu/aat/300022850">http://vocab.getty.edu/aat/300022850</a>

### 3.4 Implementation

The ontology development environment used during the case study is the Protégé ontology editor<sup>14</sup> provided by Stanford University School of Medicine. Protégé meets the requirements of the Methontology methodology and is therefore also used in several ontology engineering studies presenting Methontology based ontologies (Hennig et al., 2009; Moreno-Conde et al., 2019). Representations constructed in the specification, conceptualization, and integration stages are loaded into Protégé as classes, instances, and properties represented in OWL<sup>15</sup>.

### 3.5 Results

Applying Methontology results in an OWL formalization of the ontology, based on constructs generated using Protégé. Additionally, the ontology requirements specification document, the glossary of terms, the set concept classification trees, the data

<sup>14</sup> <https://protege.stanford.edu/>

<sup>15</sup> <https://www.w3.org/OWL/>

dictionaries, the table of instance attributes, the table of instances, and the integration document are produced as intermediary results.

The OWL ontology consists of 794 instances, 121 classes, 19 object properties, and 12 data properties. 124 alignments have been made between these entities and URIs from reused sources. The instances populating the ontology specify information describing the artworks of the artist and the related information describing locations, (roles of) individuals, equipment, glass studios, organizations, materials, collections, time spans, representations, creation processes, and the activities part of these creation processes. Figure 4 shows a part of the ontology as visualised using the WebVOWL tool.

A namespace is defined for both the ontology and instances:

```
<http://semanticweb.cs.vu.nl/test/barbarananning/>.
```

The resulting IRIs are resolvable: dereferencing these in a browser or application returns the relevant data about the resource identified by that IRI. This makes the knowledge graph a “5-star” Linked Data set. An example of such a resolvable IRI is

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<http://semanticweb.cs.vu.nl/test/barbarananning/ARTWORK_17_33_Grinding>
```

describing the process of grinding for a specific artwork. The complete knowledge graph (ontology and instances) can be accessed through a github repository<sup>16</sup> or browsed via an interactive visualization<sup>17</sup>.

Documentation is available in the form of an ontology requirements specification document, the glossary of terms, the set concept classification trees, the data dictionaries, the table of instance attributes, the table of instances and the integration document (Raven, 2020).

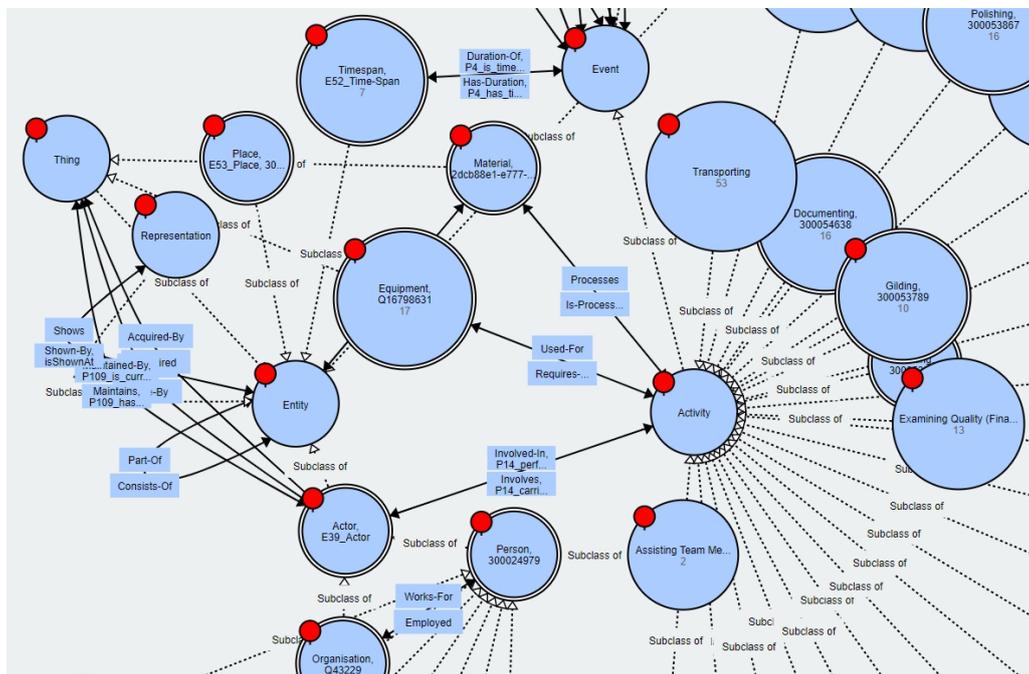


Figure 4: Detail of the WebVOWL visualization of the ontology.

<sup>16</sup> <https://github.com/biktorrr/barbarananning>

<sup>17</sup> <https://service.tib.eu/webvowl/#iri=https://raw.githubusercontent.com/DRavenNISV/Modeling-Ontologies-for-Individual-Artists/master/BarbaraNanning.owl>

## 4 Validation of the Ontology

The ontology is validated as part of the case study. This is done by appraising how well the ontology requirement specification document adjoins with the ontology implemented. Requirements are based on user stories. Analyzing whether the ontology is able to provide answers to corresponding competency questions forms the basis for validation (Baker and Cheung, 2007). Answers hence corroborate completeness of the ontology development effort.

### 4.1 User Stories and SPARQL Queries

Giving answers to competency questions requires loading the ontology into a triple store with a SPARQL query environment as a knowledge graph<sup>18</sup>. SPARQL is a semantic query language used to construct queries to RDF-based databases<sup>19</sup>.

Examining concepts, instances and properties validates the set of requirements for data publication in the Cultural Heritage domain defined by Dijkshoorn et al.

Interoperability is assured by including an extended top-level concept hierarchy and linking concepts to hierarchically structured vocabularies like the Arts and Architecture Thesaurus, wherever possible<sup>20</sup>. A property hierarchy is not included in the ontology due to a lack of sub-property relations (such as Has-Current-Keeper to Has-Former-Or-Current-Keeper<sup>21</sup>) between individual attributes or relations.

The ontology supports both object and event-based approaches for describing (the creation of) artworks. The Creation Event concept can be used to specify producing artworks and related materials, people and time spans. Object properties like Has-Depth or Made-By can also be used to describe artworks. The Creation Event concept allows for the specification of changes made to artworks over time. Meta-data and representations of artworks are separated by including EDM property Shown-By, connecting (description of) artworks to representations. Context is added to artworks by linking the artwork describing terms to other vocabularies found in Termennetwerk.

As stated in Section 3.2, to include, in this specific case, multiple views of the same artefact from different sources would unnecessarily increase the complexity of the ontology. Therefore, concepts pertinent to the fifth requirement defined by Dijkshoorn et al. are omitted.

### 4.2 Visualisation of queries

To further illustrate the use of ontologies and knowledge graphs, two examples of SPARQL queries and their visualization. Each is presented in the yasgui.org online SPARQL query builder<sup>5</sup> (Rietveld and Hoekstra, 2017), using the aforementioned SPARQL endpoint (yasgui not only allows for querying arbitrary endpoints but also to present results in novel ways).

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<sup>18</sup> <https://semanticweb.cs.vu.nl/test/user/query>

<sup>19</sup> <https://www.w3.org/TR/rdf-sparql-query/>

<sup>20</sup> <http://website.aat-ned.nl/home>

<sup>21</sup> [http://www.cidoc-crm.org/sites/default/files/cidoc\\_crm\\_version\\_5.0.4.pdf](http://www.cidoc-crm.org/sites/default/files/cidoc_crm_version_5.0.4.pdf)

Table 6: Overview of competency questions and corresponding queries and prefixes providing complete and reasonable answers

Competency Question	SPARQL Query
<b>CQ-VE-1:</b> What are the top two artworks in the Verre Églomisé collection of Nanning sorted by height?	SELECT DISTINCT ?Artwork ?ArtworkLabel ?Height WHERE { ?Artwork rdf:type bn:Glass_Artwork. ?Artwork rdfs:label ?ArtworkLabel. ?Artwork bn:Has-Height ?Height } ORDER BY DESC(?Height) LIMIT 2
<b>CQ-VE-2:</b> What equipment is used for sandblasting of the artworks within the Verre Églomisé collection of Nanning and how can this equipment be described?	SELECT DISTINCT ?EquipmentLabel ?EquipmentDescription WHERE { ?Activity rdf:type bn:Sandblasting. ?Equipment bn:Used-For ?Activity. ?Equipment rdfs:label ?EquipmentLabel. ?Equipment rdfs:comment ?EquipmentDescription. }
<b>CQ-VE-3:</b> Which artworks in the Verre Églomisé collection of Nanning are currently stored in her private collection?	SELECT DISTINCT ?Artwork ?ArtworkLabel WHERE { ?Artwork rdf:type bn:Glass_Artwork. ?Artwork bn:Part-Of bn:CollectionOfBarbaraNanning. ?Artwork rdfs:label ?ArtworkLabel. }
<b>CQ-VE-4:</b> What is the description of the technique that was last applied in the creation process of the ‘Go with the Flow’ artwork from the Verre Églomisé collection of Nanning and which parties were involved in this technique?	SELECT ?ActivityType ?DescriptionTechnique ?ActorName WHERE { ?CreationEvent bn:Created bn:Artwork_77. ?Activity bn:Finishes ?CreationEvent. ?Activity rdf:type ?ActivityType. ?ActivityType rdfs:comment ?DescriptionTechnique. ?Activity bn:Involves ?Actor. ?Actor rdfs:label ?ActorName }
<b>CQ-VE-5:</b> What are the links to the digital representations of the artworks in the Verre Églomisé collection?	SELECT ?LabelArtwork ?LabelLinkDigitalImage WHERE { ?Artwork rdf:type bn:Glass_Artwork. ?Artwork rdfs:label ?LabelArtwork. ?Artwork bn:Shown-By ?LinkDigitalImage. ?LinkDigitalImage rdfs:label ?LabelLinkDigitalImage. }
<b>CQ-CS-1:</b> What are the top three artworks in the Coloured Shadows collection of Nanning sorted by descending year of completion?	SELECT DISTINCT ?Artwork ?ArtworkLabel ?LabelYearOfCompletion WHERE { ?Artwork rdf:type bn:Glass_Artwork. ?Artwork rdfs:label ?ArtworkLabel. FILTER( strStarts(?ArtworkLabel, "Coloured Shadows")). ?Artwork bn:Created-By ?CreationEvent. ?CreationEvent bn:Finishes-With ?FinalActivity. ?FinalActivity bn:Has-Duration ?YearOfCompletion. ?YearOfCompletion rdfs:label ?LabelYearOfCompletion. } ORDER BY DESC(?YearOfCompletion) LIMIT 3
<b>CQ-CS-2:</b> What activities are part of the creation process of the ‘Beneath the Water’ artwork in the Coloured Shadows and where have these activities taken place?	SELECT DISTINCT ?NameActivity ?NameLocation WHERE { ?Artwork rdf:type bn:Glass_Artwork. ?Artwork rdfs:label ?ArtworkLabel. FILTER( strStarts(?ArtworkLabel, "Coloured Shadows Beneath the Water")). ?Artwork bn:Created-By ?CreationEvent. ?CreationEvent bn:Consists-Of ?Activity. ?Activity bn:Located-In ?Location. ?Activity rdfs:label ?NameActivity. ?Location rdfs:label ?NameLocation. }
<b>CQ-CS-3:</b> What are the materials processed in the creation process of the ‘Coral Reef’ artwork from the Coloured Shadows collection of Nanning and during which activities were these materials processed?	SELECT DISTINCT ?NameActivity ?NameMaterial WHERE { ?Artwork rdf:type BarbaraNanning:Glass_Artwork. ?Artwork rdfs:label ?ArtworkLabel. FILTER( strStarts(?ArtworkLabel, "Coloured Shadows Coral Reef")). ?Artwork BarbaraNanning:Created-By ?CreationEvent. ?CreationEvent BarbaraNanning:Consists-Of ?Activity. ?Activity BarbaraNanning:Processes ?Material. ?Activity rdfs:label ?NameActivity. ?Material rdfs:label ?NameMaterial. }

**Company based gallery visualization.** Figure 5 shows a gallery view of the objects made at glass house Jiří Pačinek. The query uses links from Wikidata (where this company is defined), through the knowledge graph, using links to the external images hosted on the Web. The results are displayed using yasgui's built-in gallery display.

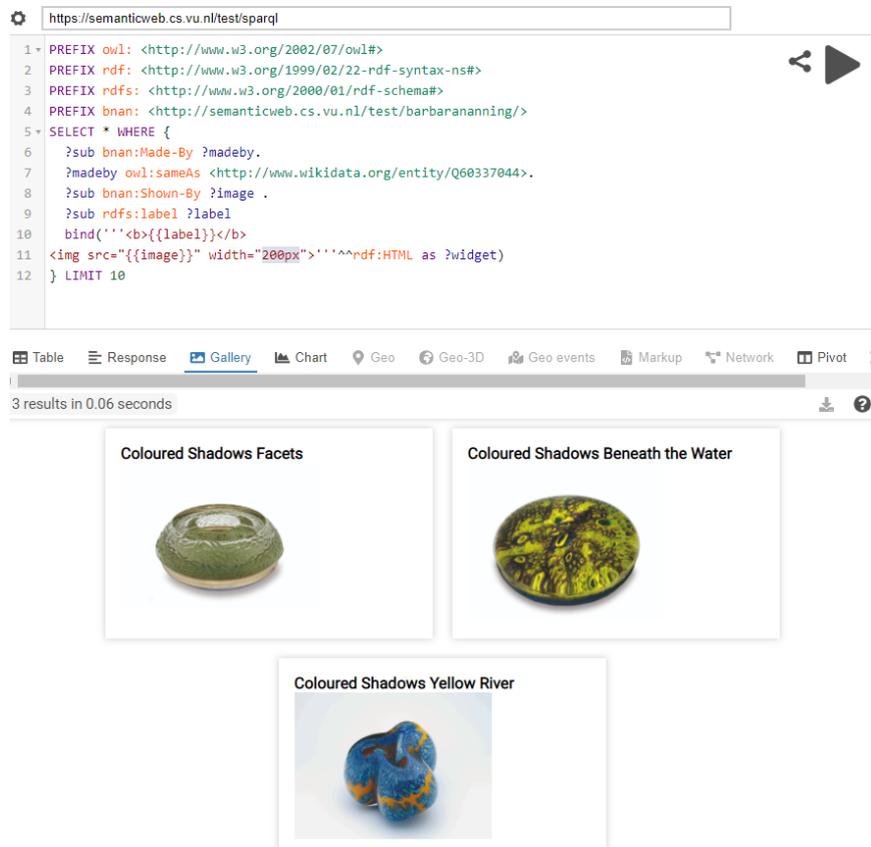


Figure 5: Result for the query to display objects involving a specific person

**Geographic visualization.** Figure 6 shows the query to retrieve all geographic locations associated with a specific artwork. Through links with the external vocabulary GeoNames, geographic coordinates can be retrieved. This allows using the built-in Geo visualization of yasgui to present the locations on a map.



dent and can further be extended by including artist-specific concepts similar to the concept classification trees defined in this study. More specific concepts related to glass-processes can be reused by other artists working in the same medium, while concepts that are idiosyncratic to the work and process of Nanning are less likely to be re-used. For new cases, we can therefore expect that the method will result mostly in concepts that are specific to that artist, but that these can be mapped to the already existing more generic ones presented here. Here we do expect a trade-off between the specificity of the ontology for the new artist and the level of re-use of previously defined concepts.

Future work includes research into the application of this and other ontologies in information extraction tasks for different end-users, as well as investigating whether more general design patterns can be derived from the ontology that can be applied to other domains, in both historical and present-day art, craft and design contexts.

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