Modelling Spatial Iconography

An Ontology Design Pattern to model visual representations on three-dimensional cultural heritage objects

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Abstract

Iconographic programs as architectural decorations, such as murals, are an important source for historical and art historical research on visual communication, but existing cultural heritage ontologies do not capture spatial relations between visual elements distributed across the multiple surfaces of a single three-dimensional object. This paper presents an ontology design pattern (ODP) that addresses this gap through a mereotopological (Region-Connection-Calculus-based) approach, grounded in a separation between a mural's material carrier and its visual/conceptual content. The ODP represents spatial relations between iconographic elements across single and multiple surfaces, fragmentary and lost regions, and temporal layers. It is derived from a competency-question-driven requirements analysis, mapped to CIDOC CRM, using heraldic murals as a case study.

Keywords

Cultural Heritage (CH), Digital Humanities, Digital Art History, built heritage, iconography, visual communication, heraldry, ontology, knowledge graph, spatial relations

1. Introduction

The paper presents an ontology design pattern, called SICON (Spatial ICONography), that allows the formalised description of spatial relations between different elements in an iconographic program,[1] using the example of heraldic murals. From a medieval or early modern historians perspective, murals can serve as an important visual source to study visual communication of representation, hierarchy, and identity [1, 2]. At the same time, they are harder to research: At lot have been damaged or destroyed (though sometimes still documented in historical texts and/or drawings) and most existing ones are difficult to access since they are in private homes. This fragmentary and dispersed character calls for methods able to integrate and query such heterogeneous sources in a structured way. Knowledge graphs offer exactly this capacity.

Existing cultural heritage ontologies focus on two distinct but (mostly) separate domains: On the one hand, frameworks such as CIDOC CRM and its extensions provide systems for describing cultural heritage objects, their provenance, and their metadata. On the other hand, iconographic classification system (e.g. *Iconclass*) offer detailed taxonomies and vocabularies for categorizing the content of individual images. However what remains unaddressed is the representation of spatial relations *between* visual elements within and across the multiple surfaces of a single three-dimensional object.

When having a single image of an iconographic program, we can of course enable Machine Learning methods or VisionLMs. But specifically in the case of murals, we face two problems: First, most murals are three-dimensional objects – so the direct spatial relation between two things on an image gets lost, because single images cannot encode the whole iconographic program. Second, murals that are either partially or completely destroyed but documented in historical sources. Since we cannot encode the information transmitted by these sources visually, we need to turn to formal ontologies instead. Of

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[1]We use *iconographic program* in the art-historical sense of a deliberately conceived, coherent ensemble of iconographic elements whose meaning depends partly on their spatial arrangement within the whole work.

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course we might employ multimodal LLMs instead to analyse such corpora made of multiple photos, images of drawings, historical texts, and 3D models. Though even ignoring the environmental costs this entails, we need in any case high-quality data for that where we can represent explicitly the complex knowledge of how these different intermedial and multimodal sources are connected to each other [3].

The presented ODP will allow for (1) encoding spatial relations between iconographic elements on single surface and (2) multiple surface murals, (3) modelling fragmented parts (partial loss), using a mereotopological modelling approach, (4) different temporal layers, and (5) as an outlook modelling source provenance, to allow for the formal description of murals that are completely destroyed, but described in written sources.

While doing so, one of the most important underlying modelling assumption is that we have to separate the *description* of a historical source/cultural heritage object from its *interpretation* and that such interpretations need to be traceable and qualifiable in a knowledge graph (using a *factoid*-based approach) [4]. The ODP is mapped to CIDOC CRM to allow for an interoperable re-use; ideally making it easily adaptable for other three-dimensional cultural heritage objects as well.

The remainder of this paper is structured as follows. We will look at related work followed by a competency-question-driven requirement analysis, based on the application of this ODP in historical research. Afterwards, the classes and properties of the ODP will be presented in detail, closed by the discussion and outlook on next steps and possible future extensions.

Although the ODP is intended to be applicable to model any iconographic programs, this paper centres in particular on *heraldic murals* that feature collections of coats of arms. This provides a more focused case study, since due to the prevalence of this type of murals, research questions are easily transferable across different examples. In addition, the presented ODP will subsequently be used in a Digital History research project, where we created a knowledge graph to describe (medieval) coats of arms embedded in their historical and material contexts of use.[2]

A final note on terminology: We will use the term *mural* throughout this paper to encompass every kind of decor applied to interior rooms. This is mainly done as a simplification because with medieval and early modern examples, it often does not make sense to distinctly separate painted walls, painted ceilings, or parts of a rooms architecture (e.g. painted beams of a ceiling) since all of them formed part of a whole decor, forming a whole iconographic program.

2. Related Work

We need to consider three perspectives: The content of iconographic programs, the cultural heritage carrier objects which depict them, and a spatial layer that describes how visual content is positioned on such a carrier object. Since these are all their own areas of research, this section is structured along these thematic layers.

2.1. Modelling iconographic content

Regarding modelling iconographic content, we can distinguish between older approaches to classify and standardise the iconographic content on the one hand and more recent works which model the description of visual historical sources as an interpretative act.

Standardisation by a controlled vocabulary is mainly done with Iconclass, originally developed in the 20th century by Henri van de Waal as a way of cataloguing large amounts of images [5]. Though its original scope is primarily focused on artworks from Early Modern Europe [6], Iconclass is still being widely used for annotating cultural heritage images [7]. With the increasing prevalence of computer vision in Digital Humanities, Iconclass is increasingly used as a description set to train machine learning models [6] as well as a reference for VisionLMs.

[2] HERALDIC identity in context (https://heraldic-identity.org/), funded by DFG and ANR, 2025–2028. Preceded by Coats of Arms in Practice II (https://digitalheraldry.org/), funded by Volkswagen Foundation, 2019–2024.

Another strand of modelling approaches is grounded on the work of Erwin Panofsky on Iconology [8], capturing the interpretative process of describing and interpreting works art from an epistemological perspective. Carboni et al. model the description of visual and iconographic representation on cultural heritage objects by integrating Iconclass with CIDOC CRM through an additional ontological layer [9]. This approach has been extended by Baroncini who adapted the epistemological interpretation process of Erwin Panofsky into a formal ontology [10]. Sartini et al. present ICON as an ontology for universal artistic interpretations, addressing the representation of multiple interpretations of artworks and their iconographic content, going beyond simple classification [11].

All these approaches model *what* is depicted in an iconographic program as well as the epistemological framework around such an iconographic description and interpretation. However, existing models to not capture *how* things are placed inside an iconographic program, namely the spatial distribution of individual elements in relation to each other. As such, our approach to capture this spatial distribution, our approach must be nonetheless compatible with the models, described above.

2.2. Modelling architecture and 3D built surfaces

Works on the three-dimensional objects themselves, including architecture, is primarily being done in the domains of Cultural Heritage studies and archeology. Here, the CIDOC Conceptual Reference Model (CIDOC CRM) has emerged as the most dominant de-facto standard, providing a formal, event-centric structure to describe cultural heritage objects in their materiality [12]. It goes beyond standardisation of metadata for heritage sciences documentation and is intended for capturing the complex temporal and causal relationships in historical objects [13].

Among the various extensions of CIDOC CRM,[3] we must emphasise *CRM for Buildings and Archeology (CRMba)*. It implements archaeological buildings documentation by modelling building structure, changes over time, dating, and stratigraphic structure [14].

Aside from knowledge representation through ontology engineering, built heritage is often represented with 3D models. There are numerous efforts to standardise 3D models for Cultural Heritage, from an extension of the IIIF standard[4] to integrations into knowledge graphs through ontologies. Bajena proposes *OntPreHer3D*, an ontology for preservation of cultural heritage 3D models [15]. Codiglione et al. propose an ontology framework for point clouds [16]. Cigognetti extend such approaches through multi-layered semantic segmentation of point clouds, integrating spatial classification with formal ontological modelling using CIDOC CRM, CRMinf, and the Conceptual Provenance Model (CPM) [17].

However, despite addressing the issue of naturally representing the spatial distribution of the individual elements of an iconographic program in an exact manner, 3D models cannot be used for objects that are partially or completely destroyed, since they are less suitable to depict epistemic uncertainty.

2.3. Spatial and topological relations in Cultural Heritage ontologies

Recent works propose integrating geometric data with semantic layers using a combination of domain ontologies and top-level ontologies like CIDOC CRM or GeoSPARQL to encode spatial relationships [18, 19]. However, these efforts regularly rely on absolute coordinates, thereby reproducing the issues of 3D models for cases where only an (incomplete) reference about the original mural exists. In addition, these approaches focus on architectural components rather than on compositional arrangements of visual content, spanning multiple surfaces.

An approach to mitigate this is using mereotopological relationships. Mereotopology is the formal study of part-whole relationships and topological relationships, thereby providing the theoretical foundation to represent spatial regions and their relationships. In our context, those are particularly relevant since they allow for region-based descriptions without using absolute coordinates.

Mereotopological relationships have been formalised in the *Region Connection Calculus (RCC8)* [20]. In the context of architectural cultural heritage, they have recently been applied as part of the restoration

[3] https://cidoc-crm.org/collaborations
[4] https://iiif.io/community/groups/3d/

of Notre-Dame de Paris by Guillem et al. [21]. This paper presents an important foundation for our work. Though focusing on the material aspects of (one specific) built cultural heritage, we can extend their approach and apply it to visual content as well. This allows us to address a few other modelling challenges not considered by Guillem et al. [21], rather than using the model for (art) historical research questions. Above all Guillem et al. [21] do not need temporality, thereby not modelling epistemic uncertainty, incomplete transmission of historic preservation states, or intermedial/multimodal relations.

2.4. The spatiality of murals in historical research

This conceptual modelling approach aligns well with historical and art historical discourses about murals. For historians the topology of visual elements to each other is generally more important than their exact placement [22]. Especially with the *cultural turn* and *visual turn* – research paradigms, that integrated sociological and ethnological perspectives into historical studies while also shifting away from an exclusive focus on written historical sources – murals have been addressed in a variety of studies from a historical perspective, that ask not only for a description and iconological interpretation of iconographic programs but additionally try to contextualise them regarding their *function* for the people who commissioned and saw them – including liturgical functions, visual communication of influence, visual communication of successful social mobility etc. [2, 23, 24, 25]. Also in the context of the cultural turn, we can see a renewed interest of heraldry as a historical source for visual communication [26, 27]. Being used on any object imaginable, heraldic murals form an important, narrowly focused case study to model iconographic programs on three-dimensional objects. Multiple historical studies, [1, 28, 29] (among others) have addressed various research questions and perspectives on source criticism when dealing with heraldic murals.

3. Requirements Analysis

3.1. Modelling requirements of painted walls and ceilings

When dealing with (heraldic) murals as a use case, we face some domain-specific requirements: visual structure & reading Directions, three-dimensional spaces, historical and material context, temporal layers, incompleteness and fragmentation, and different epistemic qualities of historical sources. In this section, we will discuss each of these challenges from a historians perspective.

3.1.1. Visual Structure & Reading Directions

Pre-modern murals consist of different zones, containing multiple individual elements. All these single parts are of course intended as to be seen together. *How* visual elements are placed determines how the whole iconographic program is read by its recipients and thereby how it is interpreted by us as a historical source.

One of the most trivial but also important example for this would be the display of (social) hierarchies on heraldic murals [30]. For example, the painted ceiling in figure 1 (left) shows the ceiling of the castle of Goldegg (located in todays Austria). The ceiling depicts a representation of the "Imperial Quarternions", which was a visual convention, often used to depict an idealised structure of the *Holy Roman Empires* constitutional nature using heraldry. The individual coats of arms represent different territories. They are visually arranged in different groups, ranked in a very specific hierarchy, pertaining to their (claimed or actual) power. Therefore, we need to encode through our model where each individual coat of arms is placed in relation to the other visual elements of the same iconographic program.

To understand these visual structures, there exist historic conventions for "reading directions", that tell us how to interpret an iconographic program. These reading direction are of course a matter of interpretation. From a western perspective, we can usually "read" murals from top to bottom and from left to right [31] – so we may often be able to infer that something that is placed at the top or top left can be considered as more important. Though this is not always the case and even less so if we look at



Figure 1: Left: "Great Hall", Castle of Goldegg (Austria). The extensive iconographic program includes a painted ceiling with the "Imperial Quarternions" (Wikimedia Commons, license: CC BY-SA 3.0 AT). **Right:** Heraldic painted ceiling in the *Musée de la cour d'or*, Metz (detail). The two wooden beams at the top have been overpainted ca. 300 years after the original creation of the ceiling (photo taken by the author, license: CC-0).

historical sources from other parts of the world. Therefore, a model needs to be as agnostic as possible and allow for "readings" of iconographic programs in multiple directions, allowing the researcher to decide for themselves how and what they want to query.

3.1.2. Three-dimensional spaces

The ODP must not only enable queries that ask for the positioning of individual visual elements in relation to each other on a single surface, but also across multiple surfaces. Firstly, this includes visual relations between elements situated on opposite or adjacent walls. Secondly, encoding a visual relation between parts of a mural that can never be seen together from the same point of view – which was sometimes used by intention as part of iconographic programs.

Drawing from this, we can formulate the following requirements for spatial relations:

- topological relations between individual iconographic elements on the same surface area
- topological relations between different surface areas (e.g. different walls in a decorated room)
- topological relations between individual iconographic elements on different surface areas

3.1.3. Historical and Material Context

As pointed out in section 2.4, historians who study murals increasingly regard them in context of their *function* as part of how the space itself was used. This also requires to not consider a mural as an isolated artwork, but directly attached to and interacting with architectural elements, among others the placement of windows, doors, or fireplaces. All of this – the functions and placements – could and did of course change, which also necessitates modelling a temporal layer. To include such commplexity in teh future, the ODP has to be designed so that it can be integrated with *CRMba* to include such perspectives into future queries.

3.1.4. Temporal Layers: Overpainting, Repainting, Restauration

Aside from the linkage of the mural to these aspects of architectural and historical context, there is another dimension, resulting from this observation: Murals changed over time – parts or the whole of them were repainted and damaged murals are being restored [1]. Sometimes this was being done to restore an original state; sometimes to change the iconographic program itself. This could include adding additional surfaces or changing specific iconographic elements – e.g. switching out a specific coat of arms with another on a heraldic mural.

Being able to distinguish these temporal layers is of course consequential for the historiographic interpretation of an iconographic program, since it can decisively change the original meaning and context it was presented in. One example can be found on a painted heraldic beam ceiling from a town house in Metz, later moved to the *Musée de la cour d'or* (Metz). The beam ceiling was created in the 14th century. All beams are separated into segments, each of them painted with a coat of arms. However, one particular segment was later overpainted and features a white horse and an emblem (see figure 1 (right)) – both not being presented in this style until the 17th century.[5]

Therefore, we need to model murals as layers, each potentially having their own temporal information, while also distinguish between (1) assigning temporal attributes to a mural as a whole, (2) to specific surfaces of a mural, and (3) to individual iconographic elements.

This does of course also include examples where part of our evidence is only fragmentary or showing gaps. Here, we face an additional requirement, since the epistemological quality of whole murals but also single parts of them may include a few levels of uncertainty. Assuming we know at least of the existence of a mural or some part of it at one time in history, we can distinguish between cases where a mural is preserved completely or partially in situ, where it has been moved (e.g. to a museum, or where it has been destroyed but documented through visual or written historical evidence.

3.2. Competency Questions

Based on these requirements, we can formulate the following competency questions for the ODP.[6] They cover spatial arrangement on a single surface (CQ-1, CQ-2), as well as more complex iconographic programs distributed across multiple surfaces, while also taking temporality and historicity into account.

- **CQ-1:** How are coat of arms visually ordered? Which of them are displayed at the top or bottom of the mural?
- **CQ-2:** Which textual inscriptions are directly adjacent to a given coat of arms on a mural?
- **CQ-3:** In fully painted rooms, what was depicted on opposite walls, facing each other?
- **CQ-4:** Which coats of arms on a mural are located on surfaces that are not simultaneously visible from a single viewpoint, as indicated by their topological surface relations?
- **CQ-5:** Which murals display a minimum number of iconographic elements from a defined program (e.g. the Nine Worthies) while also containing explicitly documented fragmentary regions, suggesting an originally complete cycle?
- **CQ-6:** Which regions of a mural contain iconographic content that was added or replaced in a different historical period than the surrounding content?
- **CQ-7:** Which written sources indicate changes made to a mural that are not directly evident from material observation of todays state of the mural?

4. The ODP

This section describes the design rationale as well as the individual classes and properties of the ODP. The alignment to CIDOC CRM v7.1.3 is isolated in a separate module merged via `owl:imports`, so that the pattern remains reusable independently of CRM while retaining full interoperability with it. The design choices are nevertheless explained below in the context of the corresponding CIDOC CRM classes and properties. Throughout this section, the following URI prefixes will be used:

```
sicon: <https://w3id.org/sicon#>
crm: <http://www.cidoc-crm.org/cidoc-crm/>
dhor: <http://digitalheraldry.org/dho/representation#>
```

[5] I thank Anne Adrian of the *Musée de la cour d'or* for explaining and contextualising this estimation.

[6] At this stage, the competency questions were mainly created by myself in accordance with the research perspectives from the literature as outlined above. In addition, the competency questions were checked by and discussed with domain experts on medieval (heraldic) murals. My thanks goes in particular to Matteo Ferrari, Maud Pérez-Simon, and Pierre-Olivier Dittmar.

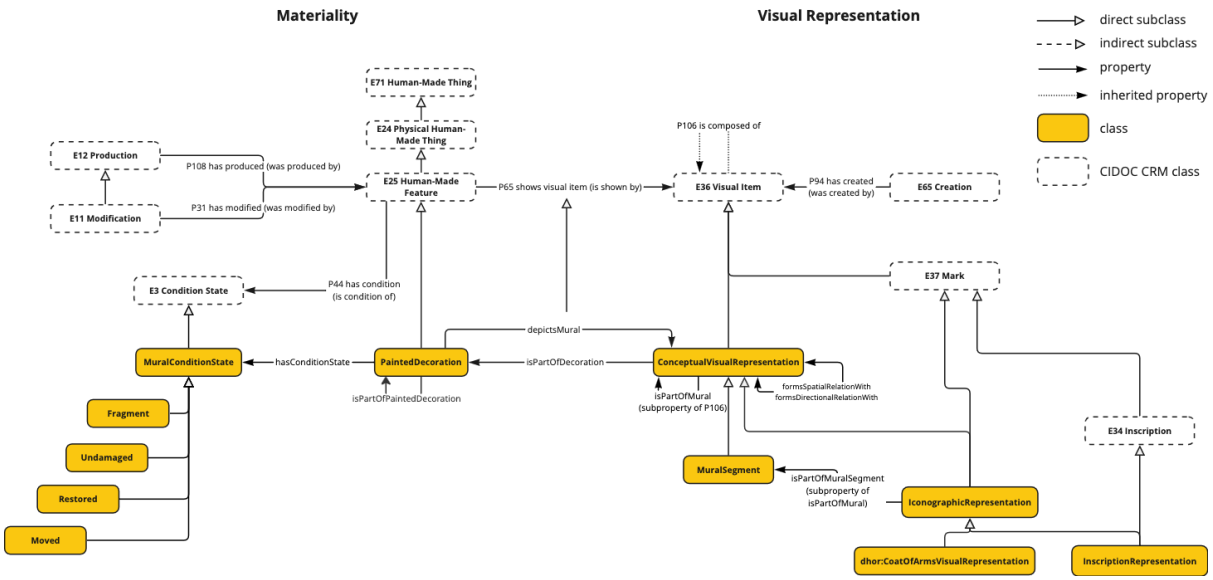


Figure 2: Classes and properties of the spatial iconography ontology design pattern (license: CC-BY Philipp Schneider).

Table 1
Coverage of the competency questions (3.2) by ODP classes and properties.

CQ	Supporting classes/properties	Coverage
CQ-1	IconographicRepresentation, aboveOf/belowOf, leftOf/rightOf	full
CQ-2	InscriptionRepresentation, nextTo, IconographicRepresentation	full
CQ-3	oppositeOfFaced, isPartOfMuralSegment, IconographicRepresentation	full
CQ-4	oppositeOfAverted, perpendicularTo, IconographicRepresentation	full
CQ-5	PaintedDecoration, IconographicRepresentation, hasConditionState, nextTo	full
CQ-6	nested MuralSegment/PaintedDecoration, E12 Production/E65 Creation	full
CQ-7	ConceptualVisualRepresentation, E65 Creation	partial (full with included provenance model)

To implement our requirements we have to start with modelling a single mural as an object. This is done by using two classes: `sicon:PaintedDecoration` and `sicon:ConceptualVisualRepresentation`. For an overview of the ODP see figure 2; the RDF serialisation is available as stated in the Resources section below. It was validated for logical consistency and coherence with the HermiT reasoner and screened with OOPS!.[7] Remaining warnings concern missing domain and range declarations on sub-properties, where the tool did not resolve inherited declarations; those were deliberately left unchanged to avoid redundant axioms.

4.1. Design rationale: Separation between visual representation and materiality

A single mural is modelled with the two central classes of the ODP: Firstly, `sicon:PaintedDecoration`, representing the mural as a material object applied to a carrier – e.g. as a layer of paint on a wall. Secondly, `sicon:ConceptualVisualRepresentation` which models what is visually represented by the `sicon:PaintedDecoration`. The visual representation of a single-surface mural uses the

[7] https://oops.linkeddata.es/

subclass sicon:MuralSegment. This modelling approach essentially captures both the material and visual aspects of a mural by splitting them into two separate classes, mapping to a similar distinction in CIDOC CRM: sicon:PaintedDecoration is a subclass of crm:E25Human-MadeFeature, sicon:ConceptualVisualRepresentation a subclass of crm:E36VisualItem. Importantly, this denotes a realisation-specific visual arrangement – the particular spatial configuration on a particular carrier, or as attested by a particular source – rather than a compositional type shared across multiple real-world objects.

This split is needed because we deal with cultural heritage objects combining a unique physical carrier with a conceptual layer whose evidentiary basis can differ. We can derive its necessity directly from CQ-7 (3.2), concerning changes to a mural not indicated by material evidence: a sicon:MuralSegment need not be grounded in direct material evidence, but can also be reconstructed from historical sources describing it, such as a written source or a drawing. Consequently, its iconographic programme can outlast its material carrier: sicon:PaintedDecoration disappears once its architectural carrier is destroyed, while a sicon:ConceptualVisualRepresentation persists as long as it remains traceable through any source, materially attested or not. Therefore, this split is a necessary precondition for representing murals that are only attested though textual sources; though this is not yet formalised in the scope of this paper (see section 5).

This design invites comparison with the WEMI model formalised in LRMoo, whose F2Expression/F3Manifestation/F5Item hierarchy offers a similarly layered treatment of conceptual and material content. sicon:PaintedDecoration corresponds structurally to F5Item, which LRMoo explicitly allows to be an E25Human-MadeFeature; sicon:MuralSegment is comparable to an F2Expression. We nevertheless did not create a full alignment. First, F2's identity criterion – any change in signs yields a new Expression – is incompatible with the gradual material degradation that our ODP treats as a condition state rather than an identity change. Second, R7exemplifies obligatorily requires an F3Manifestation for every Item, yet Manifestation is largely void of content for unique, unpublished painted objects. Third, unlike F1Work, sicon:ConceptualVisualRepresentation carries no properties for organising realisations across carriers; it is self-similarly composed of parts of the same type rather than structurally distinct from them, deliberately leaving cross-realisation identity, and the ODP's applicability beyond murals, to external vocabularies. Partial adoption of LRMoo's R15hasfragment for the fragmentation use case (CQ-5), and a fuller WEMI alignment, are left to future work.

4.2. The material layer

The material layer and all its properties is described by the class sicon:PaintedDecoration. It is a subclass of crm:E25Human-MadeFeature and intended to encompass all decorations in internal, human-made rooms that feature recognisable and reusable iconographic features.

With MuralConditionState we describe the material condition of the mural as a whole or specific parts of it, implementing CQ-5 (3.2). They may be Fragements, objects that are still as they were Unamaged, decorations that are not original but Restored (and which consequently have to be treated differently in their interpretation as a historical source), and finally murals or parts of murals that have been Moved.

4.3. The Visual Layer

The visual layer of a decoration is modelled through the class sicon:ConceptualVisualRepresentation which in turn is a subclass of the CIDOC CRM class E36VisualItem.

Similar to sicon:PaintedDecoration and sicon:ConceptualVisualRepresentation, each sicon:MuralSegment may be nested or recursive. They can cover the complete decoration of a room, as well as specific individual surfaces that form a part of it (e.g. a wall or a painted side of a specific beam from a ceiling). These segments can, in general, be arbitrarily defined by the user of the ODP. As stated before, our model needs to be as agnostic as possible with regard to scholarly interpretations and focus

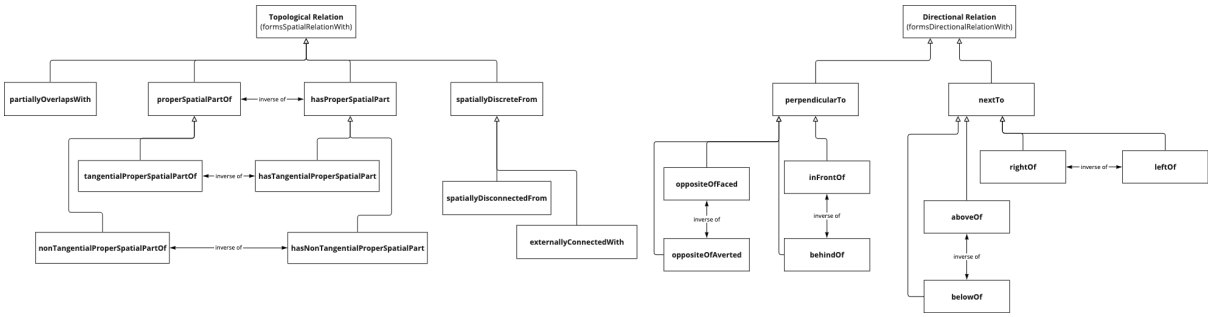


Figure 3: Properties structure of the mereotopological properties.

on the description of what can actually be observed. As an example: Given the case that we have a lot of fragmented decorations, we cannot know in every case if a collection of pigments is the whole original mural or if it composes just a small fragment of a larger decoration that no longer exists. Therefore, we need to model each surviving fragment as a distinct entity, where each of those may have their own attributes (e.g. temporal information). This implements CQ-6 (see table 1). We saw a real-world example for this requirement in section 3.1.4 figure 1 (right). Using the nested conceptualisation of a mural in the ODP together with the event-based modelling of CIDOC CRM, we can now either date the complete decoration of a room or just specific parts of it (see figure 2).

Since we want to use the ODP for historical and art historical research questions, we need to be able to precisely address iconographic concepts across multiple objects. These are therefore modelled as `sicon:IconographicRepresentations`. Like `sicon:MuralSegment`, they are a subclass of `sicon:ConceptualVisualRepresentation` and they can be part of a larger `sicon:MuralSegment` (figure 2).

In the case study used for this paper, these are mostly single coats of arms, but generally, every distinct object to which we can add an iconological layer of interpretation may be understood as an `IconographicRepresentation`. The ODP is intended to be used in a way that any iconographic vocabulary may be linked to this class. Consequently, using the case study, an `IconographicRepresentation` can for example be a visual heraldic representation (`dhor:CoatOfArmsVisualRepresentation`) or a written inscription (`sicon:InscriptionRepresentation`). This modelling approach is also a direct consequence of CQs 1-4 (3.2).

4.4. Spatial Properties

The spatial requirements from CQs 1-4 (see section 3.2) are implemented with mereotopological relations, shown in figure 3. They are split into topological relations (`sicon:formsSpatialRelationWith`) and directional relations (`sicon:formsDirectionalRelationWith`).

Directional relations distinguish how two things are placed adjacent to each other (right-left and above-below) and perpendicular to each other (e.g. two things are placed on opposite walls). Topological relations describe how two things interact as surfaces. This allows us to distinguish more precisely if two surfaces are bordering each other, if there is some degree of overlap between them, or if they are completely separated. The sub-properties of `sicon:formsSpatialRelationWith` essentially directly implement the RCC8 topologies.

Both super-properties have the class `sicon:ConceptualVisualRepresentation` as their domain and range. Therefore, the relations apply equally between individual elements, between areas, and between a single element and an area.

With directional relations we need to be explicit about the frame of reference and the perspective(s) from which it is stated that something is "right of" or "below of" something else. The mereotopological properties in this ODP are therefore defined to be used with the surface they describe as the main frame of reference. In case of a single painted wall, this would mean that something is placed right

of something else from the point of view of a person standing in front of this wall. For murals with multiple surfaces, the ODP does not allow for the use of `sicon:leftOf` and `sicon:rightOf` as directional properties to avoid ambiguous annotations. The ODP is not intended to model exact lines of sight. While this is an important parameter when studying visual communication with architectural elements, this would entail the same epistemological challenges with regard to incomplete states of preservation of decorations, as described above. However, the properties `sicon:oppositeOfFaced` and `sicon:oppositeOfAverted` allow for some queries for visual elements that can never be visible together from a single perspective.

5. Discussion and outlook

This paper has introduced an ontology design pattern to describe iconographic programs on three-dimensional cultural heritage murals based on their spatial placement on walls and ceilings as well as in relation with each other. We have shown how to employ mereotopological relations to study visual structures while allowing for interoperable connections with existing standards as well as accounting for intermedial relations between texts and preserved artifacts as well as temporal layers including partial and complete loss.

Though originally intended for heraldic murals, the ODP is more generalisable and with its core components of mereotopological properites and distinction between material and visual evidence. Although not tested this way, it could therefore be applied to the documentation and (historical) research of other three-dimensional cultural heritage objects that feature multiple surfaces that depict individual or one complete iconographic program. For the European Middle Ages and Early modern era this might include painted boxes, tapestries, altar retables, gravestones. Likewise, it may be adapted for single-surface objects; e.g. to study complex placements of individual objects on a manuscript page, allowing to study patterns across large corpora with multimodal material.

Before such an adoption though, three limitations follow from the current scope. First, the ODP provides no constraints – neither RCC8 composition-table inference, which exceeds OWL 2 DL expressivity, nor SHACL shapes – to detect contradictory assertions; consistency of the spatial layer therefore rests on the annotator. Second, the pattern has so far only been validated formally: a functional validation requires an instance dataset with the competency questions formalised in SPARQL, which is planned as part of the integration into the *Digital Heraldry Knowledge Graph*[8]. Third, this will also include a performance evaluation and – due to its deep hierarchies – possibly be extended with some shortcuts to allow for faster queries. Eventually, the ODP will be used to integrate a large corpus of heraldic decor on built heritage, based on *Armma*[9] as part of the project *HERALDIC identity in context.* Additionally, a more general application to three-dimensional historical objects will necessitate a broader evaluation by domain-experts working with a greater variety of such objects.

On the modelling side, additional future work will include mapping the ODP to other standards in the cultural heritage sector. This should include the *Historical Context Ontology (HICO)*, to model the statement provenances more precisely, a more complete integration with *CRMba* and ideally an integration with 3D models, e.g. such as presented by Cigognetti et al. [17] to make it more interoperable with other digital representations of three-dimensional cultural heritage objects.

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[8] https://research-environment.digitalheraldry.org/
[9] https://armma.saprat.fr/

Resources

The SICON ontology design pattern is published under a persistent identifier at https://w3id.org/sicon and archived under DOI: 10.5281/zenodo.22026459 (CC0 1.0). Source files are available at a Gitlab repo[10]. Its FAIRness was assessed using FOOPS![11], with a score of 91%.

Declaration on Generative AI

During the preparation of this work, the author used Claude Sonnet 5 in order to: Paraphrase and reword. Claude Opus 5 was used as support to create the documentation of the RDF for the ODP. After using these services, the author reviewed and edited the content as needed and takes full responsibility for the publication's content.

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