

The Historical Framing Problem: Temporal Modeling of Interactions between Tangible and Intangible Cultural Heritage

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Abstract

The distinction between tangible and intangible cultural heritage (CH) is problematic for modeling interactions between material and immaterial expressions of the arts and culture. This hinders capturing changes in CH objects in their cultural contexts necessary to understand their social functions and symbolic meanings. This paper addresses this problem twofold. First, after providing a theoretical-historiographical overview of the concepts of framing and historical time, the present paper proposes a historical frames system consisting of reference frames and historical frames. A model of historical frames allowing for spatiotemporal views of storylines is discussed in more detail. Second, a framework of ontological modules is provided that expresses the historical frames by extending existing ontologies. As most interactions between tangible and intangible CH are less defined, particular attention is paid to the modeling of ephemeral events. The model is designed using five types of such interactions in a case study of the late 12th century reliquary shrine of St. Servatius in Maastricht and festivities around it. The outcomes are four modules describing 1) functions of objects in context 2) frames capturing different temporal events, in particular ephemeral events, 3) the evolution of material and immaterial objects, and 4) peculiarities of ephemeral events and objects.

Keywords

Historical Frames System, Objects in Contexts, Modeling Ephemerality, Tangible and Intangible Cultural Heritage, Iconographical Change

1 Introduction

Although UNESCO defines culture as a set of spiritual, material, intellectual, and emotional features of a society or social group, it distinguishes between tangible and intangible cultural heritage (CH)¹. This distinction is reflected in semantic web studies, in which the focus of the modeling is foremost on the tangible (see the domain standard CIDOC-CRM), less on the intangible and rarely or not on the interactions between the two. The lack of modeling of interactions between tangible and intangible CH is problematic (1). The relevance of CH objects can only be grasped through the analysis of the socio-cultural contexts in which they existed. The description of such contexts provides them with the societal functions and meanings that lead to their recognition as objects that reflect the cultures and (historical) identities of certain social groups (2). Furthermore, such objects traverse different cultural systems over time, which may provide them with new physical appearances, functions, and meanings. Whereas they may be involved in established immaterial cultural practices of long duration, such as religious festivities, their physical appearance and meaning are sometimes deeply changed by ephemeral events of short duration or arbitrary decisions, such as the restoration of an object. This implies that we should consider not only immaterial CH in this context, but, more broadly speaking, every type of activity that interacts with the CH object as well. The CH catalog entries and ontology models based on them primarily focus on the

description of the physical characteristics of the artwork for use in museum contexts. However, with cited UNESCO's definition of culture in mind, such models are far too narrow. Technologies such as the semantic web offer opportunities

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to model in an encompassing way such complex relations between objects and the events that relate to them. To the best of the authors' knowledge, a study on how interactions between CH objects and immaterial practices and their evolution over time can be semantically modeled does not exist yet. To fill this gap, this paper presents theories of frames to underpin ontologies that enable expressing objects in their (immaterial) contexts over time. Frames theories are chosen as a modeling reference for this purpose because computer and artificial intelligence applications demonstrated that they can be useful for capturing semantic information related to the concepts or objects observed.

Our research questions can be formulated as follows:

- RQ1: Can frames theories help to grasp the interactions of a CH object with its immaterial cultural context(s)?
- RQ2: how can an ontological model represent the relation and mutual influence of a CH object with its socio-cultural, immaterial context(s)?
- RQ3: how can we model the regular or irregular recurrence of immaterial practices over time, which involve the use of CH objects, and invest them with meanings or new functions?
- RQ4: how can a model represent the core practices that contribute to the identification of a certain context as a set of recognizable practices (e.g., the set of beliefs and practices that are recognized as being "catholic" in Maastricht over centuries)?

To address these questions, the contribution is twofold. First, a theoretical-historiographical overview is provided of the concept of framing in computer science, artificial intelligence, and communication sciences. This is followed by a discussion of the concept of historical time in cultural- and art historic studies. These concepts are synthesized as the historical framing problem. On this basis, we propose a theoretical framework (RQ1) in which frame concepts are used to represent and analyze the storyline of objects over time. Secondly, a framework of ontological modules is introduced that formalizes the proposed theoretical framework (RQ2-4). It is further developed and tested on a case study of the late 12th century reliquary shrine of St. Servatius in Maastricht and festivities around it. This case was chosen as a golden example for its richness.

The reliquary shrine, the so-called Chest of Distress named after its proclaimed function of protecting the population of the city in times of emergency, has a rich history of immaterial practices spanning over centuries. The chest, together with other reliquaries, is carried around in the Septennial Pilgrimage Processions since the Middle Ages and surrounded by various musical, theatrical, and literary manifestations. It allows for addressing the complexity of the immaterial events related to a CH object occurring in real scenarios. Indeed, practices related to the Chest present a range of different characteristics concerning their duration, (ir)regular recurrence over time, or the impact of brief ephemeral events on the conceptual and/or material aspects of the CH object. By choosing this case, we aim to ensure that the ontology addresses the actual complexity of intangible CH practices surrounding CH objects. To this aim, the case is used to study five types of interactions between

tangible and intangible CH observed in historical frames, namely:

- Interactions between tangible and intangible CH in events that recur regularly (type 1) or irregularly (type 2) over time (Sections 9.1 and 9.2)
- Events in the restoration process leading to changes to the function (type 3) or the iconographic program (type 4) of CH objects in context (Sections 9.3 and 9.4)
- Ephemeral events that provide meaning to material objects through immaterial practices (type 5; Section 9.5)

In particular, attention is paid to the impact of these interactions that lead to transformations of functions and meanings of CH objects.

The resulting framework of ontological modules describes 1) social and cultural functions of objects in context 2) frames capturing the context(s) of CH objects, including cultural traits, immaterial CH and ephemeral events, 3) the evolution of material and immaterial aspects of CH objects, and 4) peculiarities of ephemeral events and objects.

The paper is structured as follows. Section 2 introduces the motivation of our work. Section 3 provides an overview and analysis of conceptualizations of frames in multiple disciplines of computer science and the humanities. Section 4 provides a state of the art in modeling CH contexts, frames, and immaterial culture in the Digital Humanities. Then, the proposed theoretical framework is illustrated in Section 5, followed by a presentation of the case study (Section 6). The requirements for the proposed ontological models are described in Section 7. The models are translated into a Framework of Modules in Section 8. Section 9 demonstrates the case study in models. Finally, Section 10 summarizes the discussion, conclusions, and future work.

2 Motivation

Historians of the arts in the widest sense of the word are interested in questions of how cultural artifacts function in society and which roles they play in specific cultural groups. They study what historical meaning these objects have in these roles and how this is expressed. The historical, socio-cultural contexts in which CH objects must be understood also determine what needs to be preserved and protected as CH, both tangible and intangible. The distinction between the two still has a big impact on the semantic modeling of the arts and culture. Although since the UNESCO 2003 Convention for the Safeguarding of the Intangible Cultural Heritage there has been a growing interest in its modeling, the focus is still centered on objects and aims at organizing material-based knowledge (1). In addition, in many cases, material and immaterial CH expressions interact, such as in urban rites, festivals, or processions. The mentioned Septennial Pilgrimage Procession of St. Servatius, for instance, shows interactions between material objects, such as reliquaries, and ephemeral events like reading poems, singing hymns, and saying blessings. These interactions change over time. Changes in temporal events can, in some cases, be well defined but in others are very fuzzy. Such changes are therefore not always easy to capture.

1 Furthermore, ephemerality is of particular interest in the art
 2 historical domain, in which every object created with the
 3 intention of not lasting in time is called ephemeral. When
 4 considering the past, the impact of ephemerality becomes
 5 particularly evident for scholars trying to reconstruct events
 6 such as celebrations of an ephemeral nature, including the
 7 creation and usage of objects that often did not survive
 8 through time. In such situations, reports of events, which
 9 may include visual and textual descriptions, are often the
 10 only piece of evidence that allows scholars to reconstruct
 11 ephemeral objects and events. A context expresses a
 12 historical, socio-cultural situation in which a cultural object
 13 exists. It is the cultural context that provided meaning and
 14 values for objects. This context is shaped by a system of
 15 beliefs and practices around objects (2; 3). Often, context
 16 is not only fuzzy, but also in continuous flux. Changes in
 17 context lead to the assignment of new values to objects
 18 and to transformations of culture. Historians of the arts
 19 try to identify salient historical traits of cultural contexts
 20 to describe and explain the material or immaterial aspects
 21 of cultural objects. This is not only necessary for a better
 22 understanding of cultural objects, but also to safeguard
 23 their values in legal and ethical ways as part of a cultural
 24 whole (2). For that reason, CH historians, archeologists,
 25 etc., try to frame cultural objects in their contexts. The
 26 selection of a frame or multiple frames to capture, describe,
 27 and interpret the various concepts of culture, religion,
 28 social practices, taste, style, etc., is not value-free. This
 29 selection has a great impact on how artifacts are defined
 30 and explained. Following Ted Nelson (4) we call this The
 31 Framing Problem. Previous studies in logic, linguistics
 32 and artificial intelligence formalized the concept of frames
 33 to express the relation between objects and contextual
 34 knowledge (e.g., DOLCE ontology(5), FrameNet(6), Fluid
 35 Construction Grammar(7)). Therefore, the concept of frame
 36 is deemed relevant for formalizing the contexts of CH objects
 37 in which interactions between tangible and intangible CH
 38 take place. A historical frames system with two components,
 39 reference frames and historical frames, is proposed for future
 40 applications in modeling and artificial intelligence in CH
 41 and the digital humanities. This frame system is intended
 42 to support alternative experiments in machine learning and
 43 computer vision to produce readings of cultural images that
 44 go beyond stylistic categories and include social and cultural
 45 aspects of works of art (8).

46 3 Theoretical-historiographical 47 background

48 The distinction between tangible and intangible CH was
 49 mentioned as problematic for modeling interactions between
 50 material objects and immaterial expressions in their cultural
 51 contexts. Before modeling these interactions, one needs to
 52 examine which properties are to be assigned to these objects
 53 and expressions in their contexts. Previous studies (9; 10)
 54 modeled artworks in context based on the views of art-
 55 historians Erwin Panofsky and Henri van de Waal. For
 56 modeling the topic, the visions of Panofsky and Van de Waal,
 57 since they consider visual artworks only, are too limited in
 58 scope in comparison to the UNESCO global definition of

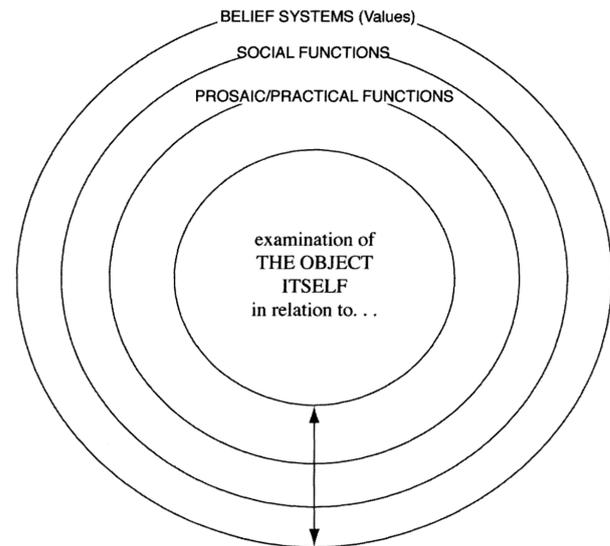


Figure 1. Tom Anderson, A Model for Cross-Cultural Examination of Works of Art (3). The object in three concentrically ordered contexts of 1 practical, 2 social functions, and 3 belief systems.

59 culture. Art-historical approaches must be enhanced with
 60 methods that examine cross-cultural issues in the art.

61 The Anderson's model (see Figure 1) puts objects in
 62 the context of practical and social functions based on
 63 belief systems. Steven Leuthold (11) proposes to create a
 64 comparative framework in which Western and non-Western
 65 art is organized and integrated into a common area of
 66 study without privileging the theories and traditions of a
 67 particular culture. From his discussion of how to frame these
 68 cross-cultural traits, it becomes clear that the modeling of
 69 interactions between tangible and intangible CH requires a
 70 better understanding of the working of frames.

71 3.1 The Framing problem

72 In his Literary Machines (4), Ted Nelson explains the
 73 framing problem from the need of the user to get a grip
 74 on the complexity of crisscrossed links in hypertext/media.
 75 He proposes frames that allow users to create their own
 76 closed contexts from larger complexes of materials. The
 77 question of how computers can understand and do justice
 78 to the complexity of human culture is probably the biggest
 79 challenge in artificial intelligence (8). Many studies in that
 80 domain refer to the work of Marvin Minsky. Minsky (12)
 81 conceived the frames as a means of better understanding the
 82 functioning of human intelligence. Frames are frameworks
 83 stored in human memory that represent information about a
 84 stereotyped situation (e.g., a catholic religious celebration),
 85 including further information about it and how to use the
 86 frame. Minsky recognized various types of frames, each
 87 with different functionalities and several types of information
 88 attached to it. The frame itself in his view is a network of
 89 nodes and relations. They have a hierarchical organization
 90 in which the top levels of a frame are fixed and represent
 91 things that are always true about the supposed situation (e.g.,
 92 a catholic mass involves a priest), while the lower levels must
 93 be filled in with specific instances or data (e.g., a catholic

mass takes place in a church). These frames (connected networks in themselves) are linked into frame systems. Minsky's notion of transformations between frames of a system consisting of frames that can be visual or non-visual is highly relevant for the proposed ontological modeling of objects and expressions of material and immaterial CH. The different frames of a system describe the transformations between one frame and another. These transformations from frame to frame represent the effect of moving from place to place but not in time, which is essential for our model of historical frames.

3.2 Formalizations of historical time

For scholars and curators interested in the creation and history of cultural artifacts, it is important that frames capture not only the effects of moving from place to place but also from time to time. For that reason, a very early discussion of a frame conceptualized for use in historical disciplines is left for last. It concerns Panofsky's interpretation of the role of frames in the description of works of art in historical time (13). Panofsky's reference frames are relational systems in/between which dynamic connections can be established. His notion of frames of reference is based on a model of theoretical physics that weaves spatial and temporal elements together in a space-time continuum (14). This latter notion is relevant for our discussion of the class SpaceTime Volume in CIDOC-CRM².

However, Panofsky's notion of frame of reference, based on a holistic space-time continuum as an indivisible unified structure, does not include the modeling of the impact of events of different durations in various places of material and immaterial CH objects and expressions in their contexts. The need for historical informed conceptualizations of time was underlined in another study (15) based on (16; 17; 18; 19). It resulted in a preliminary model with some types of synchronous and asynchronous/diachronic views (network in cross-section, longitudinal, kaleidoscopic) on historical time in storylines. Important for the proposed model is Kubler's formal and systematic approach towards the understanding of artifacts as part of a system based on formal relations. Kubler describes this system as a historical network of formal sequences that gradually change over time. In the cross-section, they show a cluster of traits in a network, and in the long section, the sequences have a fiber-like structure of temporal stages (16). Kubler did not include an image of formal sequences of durations in his book, but his mental image must have looked like Jensen's 3D semantic timeline visualization (20) (Figure 2). Our visualizations of Historical Time Frames are inspired by Kubler and Jensen's 3D timelines.

3.3 Exploring temporal interactions between tangible and intangible cultural heritage

Hou et al. (1) argue convincingly that, despite the growing number of digital research initiatives since the UNESCO 2003 Convention for the Safeguarding of Intangible Cultural Heritage, most interventions are still centered on objects and are directed at preserving material-based knowledge. In their state-of-the-art article on digital intangible CH, they observe that the challenge faced now is to find efficient methods

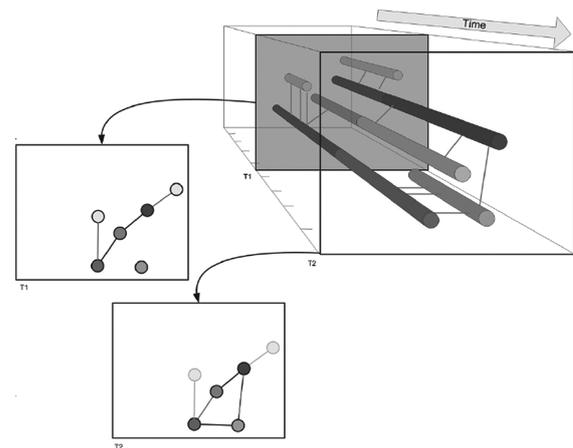


Figure 2. Matt Jensen (2006), 3D semantic timeline-visualization of development of storylines in time-intervals (longitudinal) and network of relations between storylines (transversal) similar to Kubler's description of fibers of duration and networks in cross-section

to document sources of ephemeral aspects of intangible heritage (1, p. 2). One of the requirements for archiving intangible cultural expressions is to create models that combine standardized computational frameworks with fine-grained narratives. These narratives can be anecdotal, oral, embodied, shared, and adapted to various audiences. This framework contextualizes narratives of different intangible aspects of cultural expression that evolve over time. It resonates in the proposed model of historical frames because it combines interactions between material and immaterial cultural objects that evolve over time. However, ephemeral events in tangible and intangible CH are still approached separately. Probably for their non-visual, immaterial characteristics, such events are less recognizable. Beginnings and, in particular, the endings of these ephemeral events are not clear-cut. Up to now, they can only be documented by information objects in CIDOC-CRM.

4 State of the art

4.1 Description of the socio-cultural context

In the DH domain, context is often intended to provide the provenance of information. In this sense, HiCO, the Historical Context Ontology (21) represents contextual information on hermeneutical claims by scholars based on sources' criticism and interpretation processes³. Several solutions are provided in the literature to express the provenance of assertions⁴. This includes CIDOC-CRM's E13.Attribute.Assignment class. Among these solutions, CRMInf aims at expressing the scientific process of inference when observing a given situation. It models the researcher's assumption as a belief, which is considered true or not after the application of the process. Although valuable for the CH domain, we focus on the framing of CH objects in their spatiotemporal context(s), rather than evaluating the outcome of a scientific observation of such interactions.

Nevertheless, in this study, the aim is to connect and contextualize cultural artifacts with deeper immaterial

aspects of culture. Only a few ontologies have sought to model culture. Although CIDOC-CRM does not provide a further definition of culture, the Visual Resources Association (VRA) Core ontology⁵ includes a class to describe the culture from which the item originates. The integration of artifacts with the social context is provided by the Semantic Data for Humanities and Social Sciences (SDHSS) extension of CIDOC-CRM (22). This extension focuses on social representations as systems of values and beliefs. These systems are modeled as collections of propositional objects, types, and information objects that represent the content of social representations of a given group. The Art and Architectural Argumentation Ontology (AAAO)⁶ allows to represent social facts as negotiated and agreed knowledge within a community, whose status can change over time. Although it is a valuable model for expressing the values and meaning of CH objects for certain communities, it considers only time-related variations in an agreement status, and not place. Both are necessary in cross-cultural contexts. Further ontologies that address the topic of cultural values are ValueNet (23; 24) and ICON, an ontology for artistic interpretations (25). ValueNet addresses the description of moral and social values towards the modeling of commonsense knowledge. Following Fillmore’s frame theory (26) and DOLCE’s Description&Situation Ontology Design Pattern, it models societal values as abstract descriptions, which then occur in concrete situations. In the current project, the class `CulturalValue` of ValueNet may be used to further describe how abstracts concepts (e.g., religious concepts) are expressed in certain cultures related to the CH object under observation.

The ICON ontology, developed in the domain of art history, offers means to model the subjects and meanings recognized in artworks in the form of interpretations on various levels of depth. At the deeper level of interpretation, the class `icon:CulturalPhenomenon`, and its subclasses allow us to express in more detail socio-cultural phenomena that artifacts carry according to cultural-historical interpretations.

Another aspect relevant to the modeling is the function that a CH acquires in different socio-cultural contexts or events. Several ontologies and Ontology Design Patterns (ODPs) have been proposed to represent the variation of roles taken on by people over time (27; 28; 29). CIDOC-CRM suggests modeling a change of an object’s function through an E7 Activity in which the object is used⁷. However, this solution does not seem suitable for indicating a more general use of the object that recurs in multiple situations. It also does not indicate how the function should be represented. Two further properties allow to indicate the intended use of an object (e.g., a glass has as its intended use “drinking”) or a use it acquired in a second place through, respectively, the properties `crm:P101_had_as_general_use` and `crm:P103_was_intended_for`. To the best of the authors’ knowledge, the only model addressing a change of function is the AAAO ontology. Through the class `ZE5_Function_Status`, it is possible to express that, according to a community, in a specific time period or event, the object acquires a specific function.

4.2 Framing the object in its context(s)

In the context of this work, frames are in the first place intended to temporarily isolate objects or phenomena and their contexts to observe them in more detail. They are used to observe historical events. Several ontologies address observation as an object of study. Among them, the CRMsci extension of the standard CIDOC-CRM⁸ focuses on scientific observation in various fields, including the conservation of CH. In particular, the class `S4_Specific_Observation` represents the act of capturing scientific knowledge about physical phenomena (e.g., the observation of light absorption in paintings). As its emphasis is merely on quantitative measurable data and validation in concrete applications, the CRMsci extension is considered less suitable to frame a CH object in its socio-cultural context(s).

More relevant among foundational ontologies is the Description&Situation pattern included in the foundational ontology DOLCE⁹. The description of this pattern defines concepts to create views on “relational contexts” from a set of observations (30). The DnS ODP relies on Minsky’s and Fillmore’s frame semantics theory (12; 31; 26; 32).

With the intended usage of frames in mind to observe interacting storylines of objects in context(s) from historical perspectives, the CIDOC-CRM class `crm:E92_Spacetime_Volume` is relevant. Its subclass `E4_Period` interestingly describes periods having their own identity. However, the inclusion of space together with time in the scope note and its dependency from `crm:E2_Temporal_Entity` results in not clarified relations between spacetime and perdurants in the model (see the next Section 5)¹⁰. Nevertheless, the `crm:E92_Spacetime_Volume` class is included because it meets the description of historical frames. Therefore, it is recommended to redefine class E4: Period. Being a high-hierarchy class focusing foremost on physical things, Period should be further enhanced to encompass the changes in interactions between the cultural objects and their contexts. Spacetime aspects of CIDOC-CRM are treated in more detail in CRMgeo, a module that specializes CIDOC-CRM’s Spacetime volume to be related to geographical coordinates. As the scope of the current work includes the concept of spacetime in more abstract terms than what discussed in CRMgeo, we refer, in this work, to the Spacetime Volume class as defined in CIDOC-CRM. For the reason that the CRMgeo extension extends the same class of Spacetime Volume, as historical frames do, it could be used in principle to extend them with GIS coordinates. However, defining spatial coordinates is out of the scope of this work.

4.3 Time, space and spacetime in CIDOC-CRM and foundational ontologies

As introduced in Section 3.1, the unity of spacetime in the observation of cultural and art historical phenomena is particularly relevant. After all artifacts in different geographical areas (e.g., Italy, the Netherlands) consistently vary in the same time period (13). Nevertheless, some foundational ontologies, such as the Unified Foundational Ontology (UFO), the Basic Formal Ontology (BFO) (33), and DOLCE, provide a fundamental distinction between

endurants, namely objects defined in space that maintain their identity over time, and perdurants, whose identities are defined by the participation of those objects in a moment of time (i.e. events) (5). This distinction is represented 1) in DOLCE through `dul:Object` (endurant) and `dul:Event` (perdurant), 2) in BFO through Continuant (endurant) and Occurrent (perdurant), and 3) in UFO through the modeling of two ontologies, UFO-A and UFO-B, respectively, concerning endurants and perdurants. CIDOC-CRM, the standard for the CH domain, represents perdurants as a `crm:E2_Temporal_Entity` and its subclasses, and endurant as a `crm:E77_Persistent_Item`. A relation between them is established through the property `crm:P12_occurred_in_the_presence_of` with `E5_Event`, subclass of `E2`, and `E77`.

BFO defines its entities as relating not only to time but also to space through a unity of spacetime regions. In particular, they define processes as “a temporally extended continuum, a spacetime worm, stretched out in and through the single unified container that is the entirety of spacetime”(34). Time regions are defined as the projection of spacetime regions on the temporal dimension. Although the ontology is intended to be applied mainly to the biological domain, the unity of spacetime in its formalization is of interest for the modeling of spacetime in the current paper.

A similar conception of unity of space and time appears in CIDOC-CRM through the top-level class `E92_Spacetime_Volume`. It is intended to represent the spatiotemporal extensions of phenomena. Although valuable, the introduction of this class in more recent versions of the ontology contains some unclarified relations with the definitions of perdurants and endurants. These definitions are not discussed in relation to spacetime unity. This might result in some inconsistencies. In particular, the classes `E4_Period` and its subclass `E5_Event` are defined as subclasses of both `E92_Spacetime_Volume` and `E2_Temporal_Entity`, defined as a perdurant in relation to the sole temporal dimension¹¹. DOLCE defines the space and time of objects as qualities that can vary (34). Time and space are abstract regions to which the space and time qualities of objects refer separately. In short, they are not considered as a unity of time and space. As underlined by (35), the problem of a representation of spacetime unity in ontologies remains an open and challenging one.

4.4 Tangible and Intangible Cultural Heritage

The models developed in the context of the conservation and restoration subdomains of CH are intended to support professionals in their practice. However, they are less suitable for describing the impact of decision making in removing or adding parts of physical objects on the changes in function and evolution of meaning of restored works in context.

In the above, it was argued that the methods and tools directed at intangible CH practices are still oriented toward objects and focus on the preservation of material-based knowledge (1). This is still reflected in existing ontological models. Most models of intangible CH deal with temporal aspects in musical genres or dance movements separately. However, they do not address the interactions over time between material and immaterial cultural expressions (36;

37). The Drammar ontology describes the core features of drama plays, including tangible and intangible aspects. Other models concern spatiotemporal statements regarding the physical presence of artists and exhibitions (38; 39). The same applies to the Library Reference Model (LRMoo) ontology, the CIDOC-CRM extension that expresses the Functional Requirements for Bibliographic Records (FRBR) model. This ontology has the interesting `F31_Performance` class that includes performing multiple individual works combined into a program (40). The Septennial Pilgrimage Procession in the case study would, in principle, fit in that class. However, since performance in this ontology is always associated with an instance `F1_Work` intended for describing artistic creations (e.g., theatrical plays, a musical work, or a choreographic work), it is less suitable for describing ephemeral events of religious-popular nature such as religious processions.

Particularly relevant for the modeling of the temporal characteristics of ephemeral events are two studies that discuss the development of ontology design patterns (ODPs) representing recurrent social situations or events, as immaterial practices that often recur over time. These ODPs, based on the famous horse races held twice a year between the “contrade” of Siena, the Palio (41) and on the Umbria Jazz festival (42), describe well-defined, regularly recurrent events over a long period of time. They exclude therefore irregular occurring events with fuzzy and ephemeral boundaries. Nevertheless, the Art and Architecture Thesaurus (AAT) of the Getty Research Institute provides helpful definitions for ephemeral art forms and temporary structures used in intangible CH¹². Fuzzy descriptions of time periods can be represented through the Extended Date/Time Format (EDTF) Specification created by the Library of Congress¹³. In particular, the qualifiers expressing uncertainty, approximation, and open-ended periods are useful in the context of the description of uncertainty related to ephemeral events (see Section 8.4). Nevertheless, the specification is not compatible with the XSD time format used as a standard for RDF data. This issue is addressed by the EDTF Ontology¹⁴, which allows the description of temporal entities with the EDTF specification (43) by extending the Time Ontology¹⁵.

Currently, no ontology addresses the problem of framing in an encompassing way a CH object in the interaction with its socio-cultural context. Only separate modeling solutions are offered for parts of the issue. Attention has been given to the interpretation act (HiCO, ICON) of certain facts, and on the scientific observation and inference processes (CRMsci, CRMinf). However, the question of isolating meaningful relations between material and immaterial CH practices to represent their interactions and modifications over time has not been addressed yet. ValueNet, AAAo, and SDHSS merely focus on the descriptions of socially or culturally relevant facts. However, they do not provide the means to frame these contextual facts together with the cultural objects in space and time. For the concept of framing as intended in this work, the representation of a part of the spacetime is relevant. Nevertheless, the topic is addressed in current ontologies only in relation to concrete applications in georeference systems (CIDOC-CRM’s Spacetime Volume and the CRMgeo Extension). For this reason, the current

work aims at filling this gap by providing means to describe material and immaterial CH interactions and their evolution through the spacetime continuum.

5 A Historical Frames System

Based on a previous study (15) on modeling synchronic, diachronic, and kaleidoscopic views on evidence-based Golden Agents (GA) storylines, a historical frames system is proposed. Moreover, it is underpinned by the description of the historical framing problem sketched above 3.1. This system consists of two interrelated frames: reference frames and historical frames.

Representation, observation, and understanding are human activities that take place in spacetime. Patterns herein can be recognized based on pre-knowledge, past experiences, and future expectations. This reference frame is briefly discussed. The requirements for the historical frames are described in more detail. Their functionalities and applications are described in five different types of interaction between tangible and intangible CH (Figures 11 and 12).

5.1 Reference frame

Inspired by the studies of Panofsky, Minsky, and recent studies in artificial intelligence, these reference frames are read as means to recognize and (re)organize existing and new information. This information is based on common-sense knowledge or shared experiences. The general features of knowledge and experience allow for the contextualization of existing and new information. These features are recognizable in systematic recurring patterns. However, these can also be filled in/enhanced with more associative information. A common sense/pre-knowledge frame depends on context and is domain-specific. A surgeon will read a visual image of a body differently from an art historian, although there might be some overlaps in observation. This implies that there are multiple common sense/pre-knowledge reference frames possible depending on different contexts.

These frames might be very comprehensive or have a much smaller scope, focused on details. Frames can stand next to each other, partially overlap, or become part of another. Moreover, humans' common sense/ pre-knowledge depends not only on contexts but also on dynamics herein. These frames are continuously shaped by changes in material and immaterial expressions in their contexts or by the interactions between them. An example of a reference frame already implemented in other domains is the Description and Situation Ontology Design Pattern (ODP) (30), in which the description refers to the pre-knowledge used for a certain interpretation of the observed situation.

5.2 Annotation

New insights based on information coming from the historical frames and the dynamics in pre-knowledge/common sense frames presuppose annotations of these frames. This results in updates of the reference frames.

5.3 The historical frames: spatiotemporal views of storylines

To gain more grip on temporal aspects of interactions between material and intangible culture expressions, the historical frames can be used in three different types of views to observe and analyze storylines in time. These views are based on a previous study (15) in which the potential role of historically informed time conceptualizations was explored to model storylines in CH.

1. The first is the 2D shortcut view of things in context at one moment in time represented as a two-dimensional static network. This allows for synchronic views.

2. The second is the 2D longitudinal view of things over time (without representing the contextual relations between them) as a fiber-like structure of temporal stages. This allows for asynchronous/diachronic views

3. The third is the 4D kaleidoscope view. It combines the shortcut and longitudinal views of a multidimensional network connecting links of past and even future events of a thing. This allows for combinations of synchronic and diachronic views of things (here understood as material and immaterial) in context and over time.

These synchronic, diachronic, and kaleidoscopic views on GA storylines are reused here in a wider context using historical frames. These frames support observations of temporal relationships between material and immaterial works in their cultural contexts. Following the UNESCO definition of culture, these cultural contexts can vary in nature: "the spiritual, material, intellectual, and emotional features of a society or social groups"¹⁶. These historical frames allow us to view these works from multiple spatiotemporal perspectives. This can be seen as an addition in support of the class `E92.SpaceTime.Volume` in CIDOC-CRM discussed in Section 4.

5.4 Functionalities of historical frames

To better describe the aims and characteristics of historical frames, some of their intended functionalities are described. These are aimed at capturing the interactions between immaterial and material aspects of CH in relation to time.

F1: Historical frames allow for the analysis of material and immaterial works of art in their cultural contexts.

F2: Historical frames can handle cultural contexts that differ in nature, such as spiritual, material, intellectual, and emotional.

F3: Historical frames can handle different types of time, astronomical and historical.

F4: Historical frames can handle objects that represent historical and fictional events.

F5: Historical frames allow for viewing cultural artifacts from multiple spatiotemporal perspectives.

F6: Historical frames allow for analyzing and representing different modes of time: synchronic, diachronic, kaleidoscopic.

F7: Historical frames allow for analyzing and representing temporal sequences and spatial boundaries in the real world.

F8: Historical frames allow for analyzing and representing temporal sequences and spatial boundaries in fictional worlds.

F9: Historical frames allow for analyzing and representing different boundaries of space and time: well-defined (geographical and temporal coordinates dates, hours, etc.) and fuzzy ones (ephemeral events in spacetime).

F10: Historical frames can represent the evolution of tangible and intangible CH in storylines.

F11: Historical frames can be represented as multimodal networks.

F12: Historical frames can be compared with reference frames and updated/enhanced via the annotation frame.

To explain the application of historical frames, five types of interactions of events of a different duration are explored in the case study of the Chest of Distress and the Drinking cup of St. Servatius.

This exploration, together with an analysis of the impact of these interactions on the evolution and change of meaning of cultural objects in context, serves as a point of departure for the module framework (Section 8) and the Case study in models (Section 9).

6 Case study

6.1 *The Chest of Distress of Maastricht in tangible and intangible ephemeral events*

The Chest of Distress is a 12th century reliquary kept in the basilica of St. Servatius in Maastricht (Netherlands). It is a wooden box covered with copper plates and adorned with glass and gemstones. According to legend, it holds the relics of this saint. It is named Chest of Distress because, in times of war, plagues, or other threats, it was carried around the city to ask for forgiveness and protection (44). The first documentation of such an event goes back to 1409; the last one, albeit less public, was during the Covid epidemic. Furthermore, the Chest of Distress figures every seven years in a pilgrimage procession in Maastricht. In 1958, it was decided to restore the shrine. The box with sloping roofs adorned with gilded plates is a direct reference to the Domus Aurea, the golden house. It is a representation of the holy kingdom, the new Jerusalem of pure gold that opens its gates to those saved on the day of the Last Judgment (45; 46). In addition, the stones on the shrine supported the iconographical program around the Last Judgment. They refer to the foundations of the city walls of New Jerusalem. The short gable sides of the shrine represent on one end Christ in the role of Pantocrator, i.e. as ruler on the throne. The other end shows Servatius between angles. One of them hands the bishop's staff, which signifies that God has sent him to become a bishop. During the restoration process, a committee of experts proposed several interventions that would significantly change the iconographical program of the Chest of Distress (47). For instance, after long debates of replacing the St. Servatius bishop's staff by a pilgrim's staff, it was finally decided to give him no staff at all. The iconographical program remained recognizable, albeit somewhat diluted. More drastic were decisions to replace the glass stones with precious Antique and Byzantine gemstones and to remove the votives attached by the pilgrims and inhabitants to the Chest of Distress. When the restoration in 1962 was completed, the reliquary was esthetically enriched, but with loss of devotional and popular, cultural meaning.



Figure 3. Chest of Distress in the regular recurrent event of the Septennial Pilgrimage Procession in Maastricht

This case is used to demonstrate the framing of historical events to get a better understanding of the impact of changes in the use and meaning of CH objects in their contexts over time.

Interactions between tangible and intangible cultural heritage in regular recurrent events of long duration and ephemeral events. The first documented Septennial Pilgrimage Procession took place in 1371. Since then, it has reoccurred regularly until the Reformation. This custom was reinstated in 1874 and continued with more or less regular intervals of seven years until today. The Chest of Distress is carried around the streets of Maastricht in these processions as part of a train of relic holders (Figure 3). It is surrounded by all kinds of ephemeral musical and theatrical manifestations.

Events of a very ephemeral nature during these processions are, for instance, the swinging of liturgical incense holders. The odors they spread enhance the religious and spiritual experience of the objects carried in the procession. (Figure 4).

The Odeuropa data model for olfactory heritage information that has been developed in collaboration with olfactory and art historians is useful in capturing these ephemeral events (48).

Apart from these recurrent rites in the public events of the Septennial Pilgrimage Processions or in more private devout practices of the pilgrims, there are regular recurrent events that are unique in content. Since the 20th Century, often a specific theme was attached to the septennial events for which special displays and costumes were designed. For instance, in 1962, after its restoration, the Chest of Distress was carried around again in the septennial procession with the telling theme: Proclaiming the Riches of Christ. The artist Jérôme Goffin designed the costumes and the floats around this theme¹⁷ (Figure 5).



Figure 4. Ephemeral event in which thuribles spread scents during a Septennial Pilgrimage Procession in Maastricht (The Netherlands)



Figure 6. Drawing of two lost marble panels representing the Normans setting fire to the St. Servatius church with praying canons and the Chest of Distress carried around during a state of emergency. Philippe van Gulpen, 1/1/1840, LGOG Drawings and Prints LGOG 416

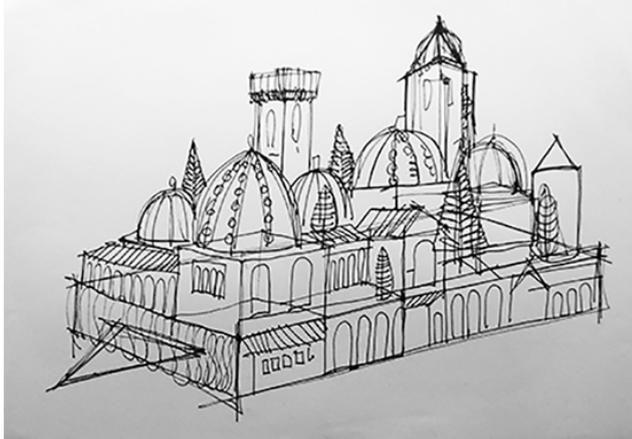
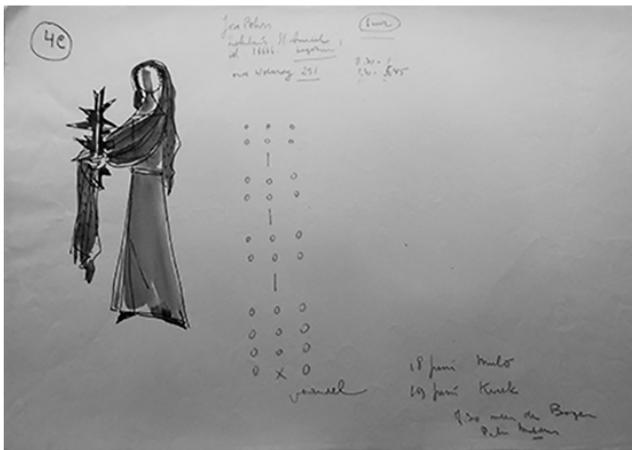


Figure 5. Septennial Pilgrimage 1962 Theme: Proclaiming the Riches of Christ. Design for costume and sketch of composition group (Above). Design of float Below). Designs by Jérôme Goffin.



Figure 7. Votive heads before (above) and after (below) the restoration of 1962. In the middle restoration drawing by J .Sprenger of 1958 with votive heads still present. Instant decision on 5 January 1962 to remove them resulted in permanent change of popular function of the Chest of Distress.

Events in the restoration process leading to changes of the function of CH objects in context. In the guidelines for the restoration it was stipulated that the temporarily removed votive heads of around 1450 would be attached to the Chest of Distress again. However, in the final meeting on 5 January 1962, it was suddenly decided not to replace them anymore. The votive heads symbolized the public role of the Chest of Distress expressing the gratitude of the inhabitants of Maastricht for protecting their city. The esthetical arguments, rather than the original function of the Chest of Distress had prevailed. The instant decision to remove the votive heads changed the public role and the devotional meaning of the reliquary shrine permanently (Figure 7).

1 *Interactions between tangible and intangible cultural*
 2 *heritage in irregular recurrent events and ephemeral*
 3 *events.* Since its first documentation in 1491, the Chest
 4 of Distress came several times out of the Basilica of St.
 5 Servatius to let the inhabitants of Maastricht say prayers
 6 for the protection against wars, epidemics, and other threats
 7 to the city (Figure 6).

Events in the restoration process leading to changes in the iconographic program of CH objects in context. It was mentioned above that the bishop's staff of St. Servatius was removed. It has an important meaning in the iconographic program because it was handed by an angel to Servatius on the authority of God. By removing this staff, this authoritative role became less prominent (Figure 8).



Figure 8. Servatius with and without bishop's staff hold by an angel at his right side before and after restoration



Figure 9. Empty setting for missing crystal glass stone (left) Byzantine cameo head added during the restoration of 1962 to embellish the Chest of Distress but with loss of popular meaning.



Figure 10. Ephemeral event of drinking from Servatius's cup that according to legend was handed to him by angels during his pilgrimage. The legend and the custom of pilgrims drinking it from it for healing provided new meaning to the Roman drinking vessel of the 1st C. (left). Placement of the Servatius's drinking cup in a chalice during a restoration of 1626/27 for the protection of the object for future use (right).

to be from the fourth century, since it was given to the saint during his lifetime (51). However, during one of its restorations, it came to light that it was actually a Roman drinking cup from the 1st Century A.D. Apparently, many pilgrims drank from it because around 1625 it was decided to restore the glass cup that gradually fell into pieces. At the same time, a painting was commissioned that is not known anymore but had the text: "Effigies scyphi divi Servatii ad vivum anno MDCXXV" (50, p.220). The restoration took place in the years 1626/27, and the cup was placed in a chalice to protect it. By the end of the nineteenth century, when the Septennial Procession was reinstated, the drinking cup occasionally made part of the processions (50, p.228). Furthermore, during the daily presentation of some of the reliquaries and sacred cloths from the dwarf gallery of the church, pilgrims were invited to drink from the cup¹⁸. This usage remained in place, and it is reported that in 1918, after so many people had sought protection against the Spanish Flu by drinking from the cup, it needed to be restored. Once again, the restoration came with a new painting. The painting by an unknown Mosan artist represents the cup handed to St. Servatius by angels. In 1935, the cup received a new holder and was placed in a small shrine where it could be seen from all sides (Figure 10). In 1972, the cup was professionally restored in Mainz and after its return placed again in the Servatius Basilica Treasury (50).

6.2 Competency Questions

Following this rich case study, competency questions are formulated that a formal model of interactions between tangible and intangible cultural aspects should be able to address. They are based on the functionalities of the historical frames proposed above. The competency questions successively deal with contextual features of an object and the evolution of an object. Furthermore, they address the function and iconological meaning of cultural objects, and finally their roles in recurrent and unique ephemeral events.

Contextual features (F1, F2, F4, F7, F9, F11)

Q1: What is the historical frame of the object in its original context (i.e., the context in which the object was created)?

1 Furthermore, it was decided to embellish the top of the
2 Servatius' side with an antique gem that was bought for
3 the occasion (Figure 9). This addition replaced crystal-glass
4 stones that, according to popular belief, had purifying power.

5 *Ephemeral events providing changes in meaning to mate-*
6 *rial objects by immaterial practices.* Several ephemeral
7 events take place during pilgrimages not only in the orga-
8 nized urban tour but also in more intimate devotional
9 expressions of pilgrims. Pilgrims visiting the basilica of
10 St. Servatius not only could observe devotional objects but
11 were also allowed to touch them or interact with them in
12 different ways. One of the highlights was drinking from
13 Servatius' Drinking Cup (for the first time documented in
14 1433), from which, according to legend, the saint drank
15 himself. It was offered to him by angels sent from heaven
16 during his pilgrimage (Figure 10). The testimony of such
17 an event can be found in the diary of the artisan Arent
18 Willemsz of the northern part of the Netherlands, who visited
19 Maastricht on his pilgrimage to Jerusalem (49; 50). A canon
20 showed the pilgrims the "drinking cup of which Sint-Servaas
21 used to drink, which gave many people health, and we drank
22 from this glass ourselves" (49, p.17).

23 After a mea culpa, mea culpa, they were shown several
24 relics of St. Servatius and "the gilded shrine that in times
25 of disasters was carried around by the canon through town
26 to beg for mercy and the people were blessed with Servatius'
27 key to heaven"(49, p.17). The drinking cup was long believed

Q2: What is the historical frame in which the object acquired a new meaning or function?

Q3: What are the historical frames that the object traverses?

Q4: What are the beliefs and ideas related to a historical frame?

Q5: To what culture do the traits observed in a historical frame belong?

Q6: What is the relationship between different instances of historical frames (e.g., frames including others, overlaps, etc.)?

Q7: What are the time and space coordinates observed by the historical frame?

Q8: What is the duration of the ephemeral event observed by the historical frame?

Evolution (F10)

1) *of the physical object;*

Q9: What are the physical variations of the object?

Q10: What is the material intervention that modifies the object?

Q11: What is the immaterial intervention that modifies the object?

2) *of the function*

Q12: What are the different functions that the object acquires in different contexts?

Q13: What is the change in function due to material or immaterial interactions?

3) *of the iconographical meaning*

Q14: How did the iconography vary over time?

Q15: How did the change in iconography affect the function/meaning of the object?

Q16: What is the change in iconographic meaning due to material or immaterial interventions?

Recurrent and unique ephemeral events (F7)

Q17: What are the traits of a recurrent event present on every occasion?

Q18: What are the functions that objects have in the context of recurrent events?

Q19: What are the specific features that occur in a unique event (e.g., the procession that took place in 1881)?

7 Requirements

To formally represent the complex interactions of cultural frames with immaterial practices as exemplified by the case study, the model should address different requirements. We list them according to four thematic areas that will be addressed by single modules:

R1 *function of the object in relation to immaterial aspects.*

The CH object may change its function according to its context(s). This can range from a cultural context to unique or repeated events. As immaterial CH events are complex objects that may occur once or multiple times at regular or irregular intervals, the relations between the function of the object and such ephemeral characteristics should be addressed as well. Therefore, the sub-requirements for representing the function of the object are:

1. representing the nature of the objects' function
2. the function should be related to the context in which such a function occurs
3. the model should allow for specifying the immaterial events in which particular functions take place (e.g., a religious parade)
4. the model should include the representation of the (ir)regular recurrence or uniqueness of ephemeral events in which the object acquires a function

R2 *contextual features:*

1. the model should represent the interactions of a CH object with one or multiple contexts it traverses
2. it should relate the contemporary culture, beliefs and ideas relevant to the understanding of the object to the object itself
3. it should be possible to specify both the time and space coordinates of the context(s) in which the objects are observed
4. different levels of granularity in the description of the context(s) should be included. This also applies to overlapping relations with other contexts

R3 *physical and conceptual evolution*

1. the model should include the description of physical (e.g., a restoration) and conceptual (i.e., change of iconography, meaning, function) evolutions of the object
2. it should relate such variations to the events causing them
3. it should include a representation of the versions of the object

R4 *ephemerality:*

1. the model should describe which events or objects are considered ephemeral
2. it should include descriptions of fuzzy time periods, which start and end present approximation, open-ended periods, and indeterminacy
3. it should include means to indicate the order in which events occur, even in the absence of time indications

Furthermore, we define the purpose, scope, and usage of the ontology according to the *Ontology Requirements Specification Document (ORSD)*(52), illustrated in [Table 1](#).

8 Models: A Framework of Modules

After having introduced the historical frames system in [Section 5](#), we will first explain its working in the context of the case study described in [Section 6](#). This allows us to visualize some of its functionalities before creating an ontological framework. [Figure 11](#) visualizes the three different spatiotemporal views of storylines explained in [Section 5](#) in general. [Figure 12](#) visualizes in the rounded squares left and right above, two different 2D views of events in two storylines. The first deals with the story of Servatius' Chest of Distress, and the second one with his

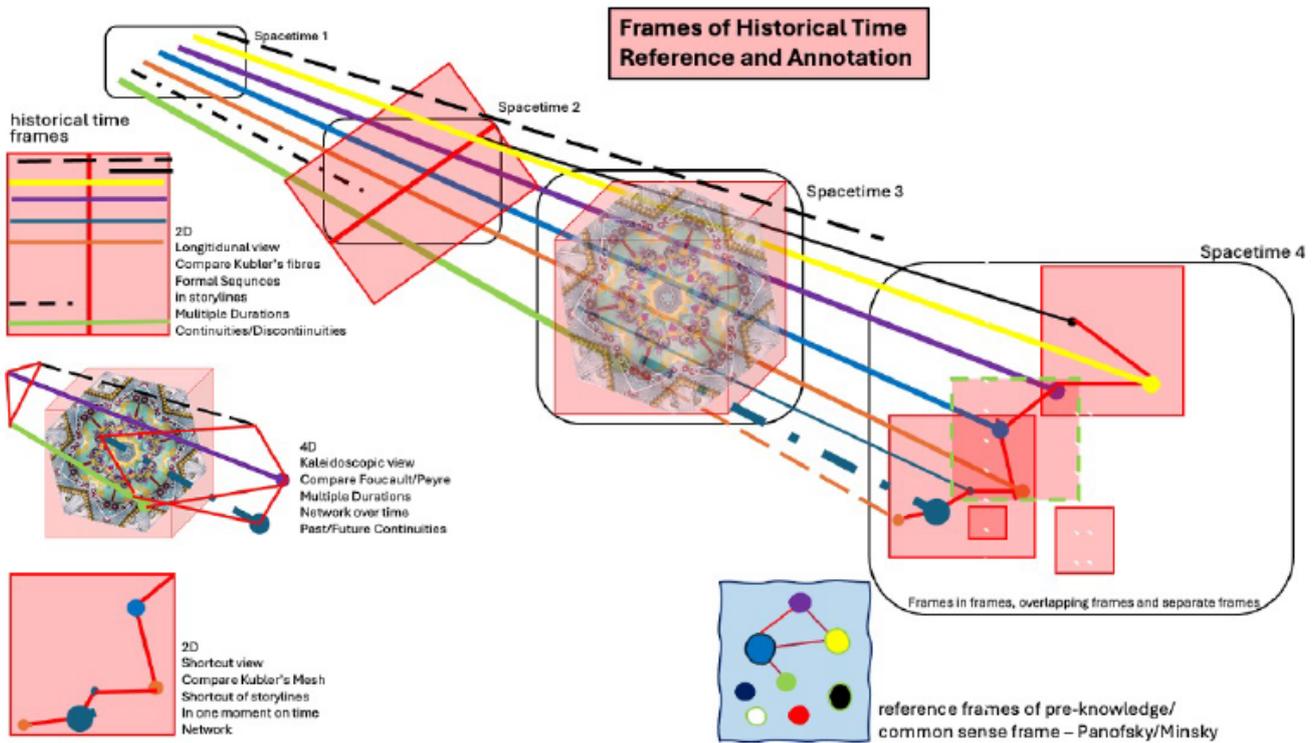


Figure 11. Visualization of Historical Frames System Longitudinal, Kaleidoscopic and Short Cut Views of Storylines in Spacetime: Historical Frame and Reference Frame

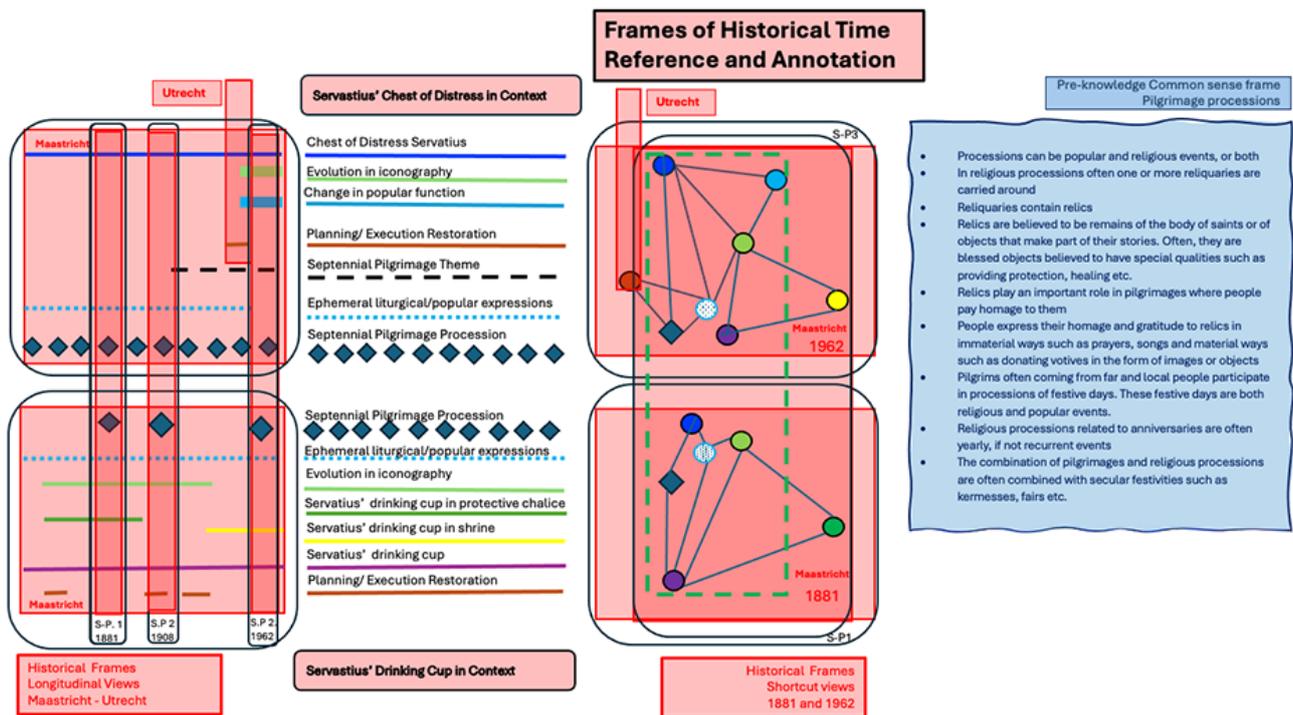


Figure 12. Visualization of Historical Frames System. Short Cut and Longitudinal Views of Storylines from the St. Servatius case in Spacetime Historical Frame with Reference Frame

1 Drinking Cup. The two top-and-bottom rounded squares
2 at the left side with 2D longitudinal views allow us to
3 compare these two storylines over time. They are made up
4 of parallel lines that, in some cases, are not continuous.
5 These continuous and broken lines express respectively the
6 duration of events and intervals between them. In three
7 chosen years in spacetime SP1881, SP1908, and SP1962

(darker orange), we can observe the co-occurrence between
8 events in these storylines. In those years, for instance, both
9 the Chest of Distress and the drinking cup were present
10 in the Septennial Pilgrimage Procession (see the chain of
11 rhomboids, each standing for seven years), but we cannot
12 see how these objects and their contexts are connected. The
13 rounded squares on the right show snapshots of two of three
14

Table 1. Modeling requirements according to the Ontology Requirements Specification Document (ORSD)

Requirement	Description
1. Purpose	The ontological framework aims at representing different types of interactions of physical CH objects with their socio-cultural context, with a particular focus on immaterial practices. It includes both descriptions in specific moments and evolutions over time and space, such as physical or immaterial changes of the object resulting from such interactions.
2. scope	The ontological framework is intended to be used in the CH sector. It is currently limited to the representation of shared knowledge, therefore excluding the representation of questionable, conflicting considerations which can be linked to a single author.
3. implementation language	OWL2
4. intended end users	User 1. Digital cultural historians, and generally workers of DH-related aspects in the CH sector, who need to represent in a more granular way the interrelations of CH objects with relevant immaterial aspects User 2. Developers and computer scientists aiming at creating further applications of cross-cultural understanding of CH objects, especially in the AI field
5. intended uses	Expressing in a machine-readable format the complex interactions between contemporary culture and immaterial events, and thoughts that eventually influenced CH objects themselves, their function and/or meaning.
6. Ontology requirements	
6a. Non-functional requirements	The ontological framework must reuse, when possible, available ontologies. If new classes are created, they should be aligned to the domain standards or foundational ontologies. The structure of the ontology should be modular
6b. Functional requirements	Groups of CQs as expressed in Section 6.2
7. pre-glossary of terms	Frame (Nelson); Function, Social and practical function (Anderson);

of these years, 1881 (bottom) and 1962 (top), in networks. They show which events in each year had a meaningful relationship with each other, but not whether this lasted a long time or was interrupted in regular or irregular intervals. For example, based on the legend of Servatius, there is a relationship between the iconographies of the cup and the Chest of Distress expressed by the light green dots. However, we cannot read from this network representation that the iconography of the cup started to evolve in the 19th century, while the change in the iconographic program of the chest occurred between 1958 and 1962. For the reason that both iconographies are related to the story of Servatius, they are part of overlapping networks, indicated by the dotted line in green projected over the two rounded squares. The dark green and yellow dots standing, respectively, for the drinking cup in the chalice and in a shrine are each connected to these overlapping networks with the drinking cup and its iconography. However, they are not directly linked to each other because in the first case, people could drink from the cup, while in the second one, no tactile interaction with it was possible anymore. These 2D representations of temporal durations/intervals and network relationships at particular moments in time are visualized in abstract form in the 4D image that is diagonally projected in Figure 11. The 4D visualization combines three-dimensional space with time in a spacetime volume in which the interactive events between these storylines take place in history. These events run through various types of frames, overlapping, separated, or within each other. These frames stand perpendicular to the storylines to analyze particular interactions between material and immaterial CH at chosen moments of time. Next to these representations of frames of historical time, the rectangles in blue with undulating outlines represent reference frames. These reference frames are based on fuzzy pre-knowledge and common sense. For example, there is a long history in which relics are carried around in processions. Those processions often occur at regular intervals and are not seldom combined with other non-religious festivities such as kermesses. Such pre-knowledge is useful for recognizing

meaningful patterns that can be expressed in networks as a base for further modeling. Here, a first attempt is made to translate part of this framework system, the historical framework, into an ontological framework of modules. The modeling is based on the characteristics of the five types of interactions between the tangible and intangible CH of the selected case study. This enabled defining the competency questions (Section 6.2) to verify whether existing ontologies could meet the requirements 7.

As some solutions could be covered by existing ontologies, they are extended only if needed in separate modules, following a modular compositional method. The reused solutions, along with the proposed extension, is illustrated in detail in the following sections. Each module addresses a specific task, following the requirements groups stated in Section 7. They are integrated through relations in a unique final framework for observing interactions between material and immaterial objects in their cultural contexts. This choice is motivated by the fact that the chosen ontologies (CIDOC-CRM, DOLCE, and the GA storyline model, developed in UFO) are based on different principles. This might potentially be a challenge to align them. Therefore, no common alignment of classes is provided, but they are related by their properties. SAMOD (53), an agile methodology for ontology development was followed because it divides the modeling process into iterations. Each module was developed through a separate iteration and tested by performing the relevant competency questions (Section 6.2) over data describing the St. Servatius case.

The framework consists of four modules, namely, Object in Situation, Historical Frame, Evolution, and Ephemerality, which are described in more detail below. The project code and documentation are provided on GitHub¹⁹. The ontological framework was assigned a permanent URI namespace to guarantee the sustainability of the resource over time:

- www.w3id.org/chint/ontology/ leads to the raw ontology file

- <https://w3id.org/chint/docs/> leads to the ontology documentation
- <https://w3id.org/chint/development/> leads to the Github repository illustrating the development

8.1 Module 1: Object in situation

The Object in Situation module (See Figure 13 and Tables 3 and 5²⁰) addresses the group of requirements R1, concerning the function of the object in relation to a context and/or immaterial practices. To this aim, it is based on the theoretical model of Anderson illustrated in Section 3. This describes the object within the belief system that gives it its specific functions and meanings. It reuses the solution proposed by the AAAO ontology to represent the function ascribed to an object by a community, namely, the class `aaao:ZE5_Function_Status` and its related properties. This class represents the function as an institutional fact of a temporal nature. The object acquiring the function is specified through the property `aaao:ZP14_has_functional_subject`. The function is ascribed through `aaao:ZP15_ascribes_function`, which associates an instance of `crm:E55_Type`. As the model does not offer a distinction between a practical and a social function, stated in the Anderson’s model, we introduce a class `Function`, subclass of `crm:E55_Type`, and two subclasses, `:PracticalFunction` and `:SocialFunction`. They represent respectively social and practical functions. Another extension proposed is the relation `:hasFunction`, intended as a shortcut of the longer path associating the function to the object through the `aaao:ZE5_Function_Status` class. Further information can be described by reusing properties inherited from the superclass `aaao:ZE1_Institutional_Fact`. The relation `aaao:ZP4_holds_for` indicates the community for which the indicated status holds (e.g., the healing function of St. Servatius cup holds for the community of Catholics).

In the module, the context in which the function is observed can be specified with different levels of detail, namely, as a spatiotemporal frame, a single event, or a series of events recurring over time. The first option describes the context in a wide sense by using the class `:HistoricalFrame`. This is explained in more detail in the following module. The function status can be related to the historical frame through the relation `:hasContext`. If the function is recognized only in the occasion of a specific event, the property `aaao:Z75_applies_for_context`, relating the status to an event, can be used. Finally, the status can be related to events recurring over time through the property `:includesFact`, which connects the newly added class `:ObjectInRecurrentEvent`, explained below, with the function status acquired.

The class `:ObjectInRecurrentEvent` is introduced to represent situations collecting events that are repeated over time and share the same characteristics, such as the Septennial Pilgrimage Processions. For this reason, it is declared a subclass of `dul:Situation` and `dul:Collection`, following

the modeling solution provided by (42; 41). The property `:includesEventsOfType` specifies the unifying type of events included in the collection (e.g., “procession”). The class is then further specialized in two subclasses, namely `:ObjectInRecurrentIrregularEvent` and `:ObjectInRecurrentRegularEvent`. Whereas a regular time interval in which the event is repeated over time can be specified for the latter, the former has no predictable time constraints related to it. As the latter class presents characteristics similar to the Recurrent Event Series pattern (42), alignments and the reuse of some classes and properties (e.g., `rss:hasUnifyingFactor`) are provided. The Recurrent Event Series pattern is preferred over the Recurrent Situation Series pattern, as the class `dul:Event` seems more suitable to describe the occurrence of CH events such as religious processions that were held in the past. Furthermore, the class `dul:Event` can be aligned with `crm:E5_Event`, which facilitates the use of different ontologies in the same descriptive framework. The cited ODPs (42; 41) allow expressing immaterial practices recurring only regularly over time. Therefore, they only partially fulfill the requirement of describing various types of repetitions of immaterial CH practices (uniqueness, irregular and irregular repetitions). For this reason, we partially repeated and extended the modeling to encompass other types of recurrence.

8.2 Module 2: Historical Frame

The Historical Frame module, presented in Figure 14 and Tables 6 and 7, is intended to relate the object under observation to the cross-cultural system. We identified such a system in Anderson’s model and included it in the historical frame definition provided in Section 5. Furthermore, it is addressed in the group of requirements R2. Mostly based on CIDOC-CRM, it integrates a class from the ICON ontology, namely `icon:CulturalPhenomenon` and its subclasses `icon:Belief`, `icon:Tendency`, `icon:CulturalValue`, and `icon:Attitude`²¹.

The module is centered around the class `:HistoricalFrame`, which isolates a part of the spacetime continuum to frame the socio-cultural context of the object under observation. In this way, it captures the space-time continuum to connect observed cultural object(s) with socio-cultural characteristics of the same context(s). The class is declared as a subclass of CIDOC’s `E92_Spacetime_Volume`²². Every object under observation is related to a Historical Frame through the relation `:hasContext`. The subproperty `:hasCreationContext` distinguishes the original created Historical Frame from the following ones (e.g., the Roman cup has as creation context, which is captured by a frame that refers to the Roman culture, in which context the artifact was created). The domain of the property is deliberately broad to allow for the inclusion of the object, the events, and the situations in which the object participates. These situations can be related to different cultural contexts.

The properties inherited from `E92_Spacetime_Volume` express relations between the frames (Requirement R2.4). These are inclusion (`crm:P10_falls_within`), overlap (`crm:P132_spatiotemporally-`

Table 2. list of prefixes

Prefix	Url
:	Proposed classes and properties
aaaa:	https://ontology.swissartresearch.net/aaaa/
crm:	http://www.cidoc-crm.org/cidoc-crm
icon:	https://w3id.org/icon/ontology/
ga:	storylines UML model (15)
dul:	http://www.ontologydesignpatterns.org/ont/dul/DUL.owl#
res:	http://www.ontologydesignpatterns.org/cp/owl/recurrenteventseries.owl#
rss:	http://www.ontologydesignpatterns.org/cp/owl/recurrentsituationseries.owl#
time:	http://www.w3.org/2006/time#
edtf:	https://periodo.github.io/edtf-ontology/edtf.ttl#
xsd:	http://www.w3.org/2001/XMLSchema#

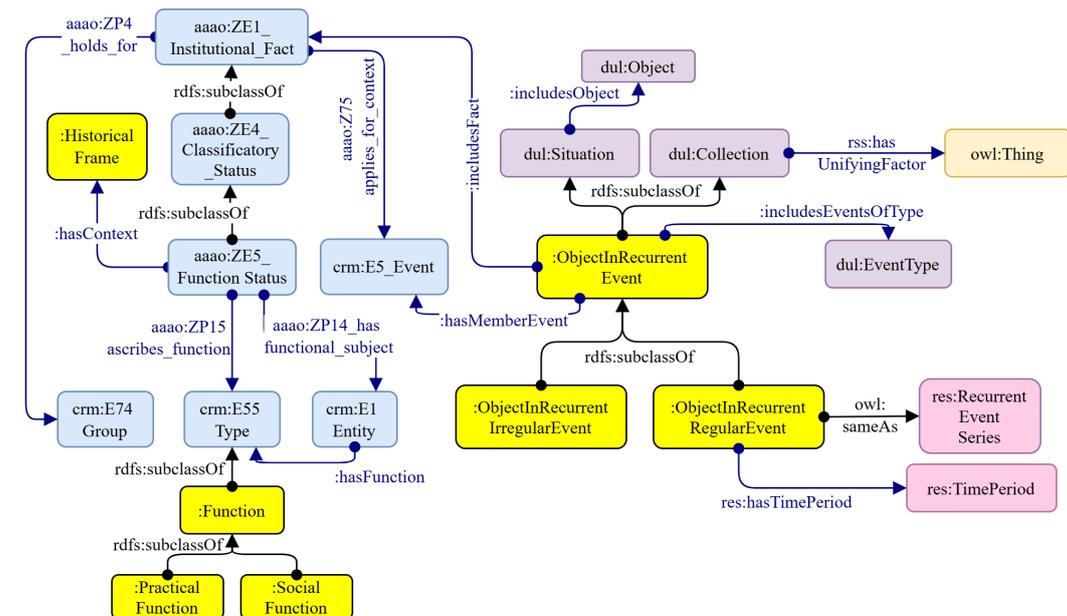


Figure 13. Module expressing a function an object acquires during a specific cultural event or in events repeated over time in a historical frame. New classes are marked in yellow.

Table 3. Newly added classes of the Object in Situation module (Module 1)

Class	Alignment	Description
:ObjectInRecurrentEvent	subclass of dul:Situation,	Situations including a CH object and an event repeated over time, either in regular or irregular intervals, presenting unifying characteristics.
:ObjectInRecurrentEvent	subclass of dul:Collection	A situation grouping events in which the same object participates having similar, unifying characteristics over time (e.g., function).
:ObjectInRecurrentIrregularEvent	:ObjectInRecurrentEvent	
:ObjectInRecurrentRegularEvent	subclass of :ObjectInRecurrentEvent;	A situation in which unifying characteristics of events regularly recurring over time are identified, and the time interval with which they are repeated can be indicated.
:ObjectInRecurrentRegularEvent	owl:sameAs res:RecurrentEventSeries	
:Function	subclass of crm:E55-Type	A class identifying the function that an object acquires
:PracticalFunction	subclass of :Function	A class identifying the practical function that an object acquires (e.g., the "drinking" function of a vessel)
:SocialFunction	subclass of :Function	A class identifying the socially attributed, non-strictly practical function that an object acquires (e.g., the healing function of St. Servatius cup in a catholic context)

1 overlaps_with) and separation (crm:P133-
2 spatiotemporally_separated_from).

3 A Historical Frame can express the traits of a spe-
4 cific or multiple culture(s) (:Culture) charac-
5 terizing it through the relation :refersToCulture and
6 establishing a relation with specific aspects (relation
7 :includesCulturalTrait; requirement R2.2). As
8 culture is a fuzzy concept, the boundaries of which are

usually not well defined and stable over time (55), frames are
used to isolate and identify traits that are relevant for making
meaningful observations of the object. These are known to be
present for the duration of the spacetime volume identified by
the frame.

Finally, the module is integrated with further properties.
The property :believedThing enriches the class
icon:Belief by relating it to the actual content believed.

Table 4. Reused classes in the Object in Situation module (Module 1)

Class	Description
aaao:ZE5.Function Status	“An instance of function status is the collective ascription of an operative functionality to an object by a community. The substance of the function status is the communal commitment to relating to and / or using the object in question according to a designated function.”
crm:E74.Group	“This class comprises any gatherings or organizations of human individuals or groups that act collectively or in a similar way due to any form of unifying relationship.”
crm:E5.Event	“This class comprises distinct, delimited and coherent processes and interactions of a material nature, in cultural, social or physical systems, involving and affecting instances of E77 Persistent Item in a way characteristic of the kind of process. Typical examples are meetings, births, deaths, actions of decision taking, making or inventing things, but also more complex and extended ones such as conferences, elections, building of a castle, or battles.”
res:TimePeriod	Class indicating the “time period that has typically to elapse before the next event is held, which is usually approximate (e.g., yearly, monthly, etc.), and is different from the actual time between two events, which can be derived from the time intervals computed between any two members” (42).
dul:Event Type	“A Concept that classifies an Event. An event type describes how an Event should be interpreted, executed, expected, seen, etc., according to the Description that the EventType isDefinedIn (or used in)”
:HistoricalFrame	Class, defined in the Historical Frame module, which represents the socio-cultural context in space-time that is the context of the observed object.

Table 5. Properties of the Object in Situation module (Module 1)

Property	Domain	Range	Description
Newly added properties			
:includesEvents OfType	:ObjectIn Situation;	dul:Event Type	Relate the event series with the type of event that is included (e.g., mass, procession). It is a property chain for :hasMemberEvent o dul:hasEventType.
:hasMemberEvent	:ObjectIn RecurrentEvent	dul:Event	Property to indicate the events of a series based on the model of the Recurrent Situation and Recurrent Event Series ODPs, which property cannot be directly reused as they have a different domain.
:includesFact	:ObjectIn RecurrentEvent	aaao:ZE1.Institutional.Fact	Property expressing the fact that the indicated institutional fact (for example, the fact that the CH object holds a function) is observed in the situation that represents a series of events repeating over time.
:hasFunction	crm:E1.Entity	crm:E55.Type	Property expressing the function that a CH object has. It is a shortcut for the longer path aaao:ZE5.Function.Status aaao:ZP14.has_functional_subject crm:E1.Entity; aaao:ZP15.ascribes_function crm:E55.Type. It is declared as subproperty of crm:P2.has_type and as a superproperty of crm:P103.was_intended_for and crm:P101.had_as_general_use, which add more detail to the usage or function that the object has.
Reused properties			
aaao:ZP14.has_functional_subject	aaao:ZE5.Function.Status	crm:E1.Entity	“This property is used to indicate the entity for which a certain functional classification is taken to hold by the instance of functional status.” (54)
aaao:ZP15.ascribes_function	aaao:ZE5.Function.Status	crm:E55.Type	“This property is used to indicate the type of function which is indicated as holding for the subject of the function status.” (54)
aaao:Z75_applies_for_context	aaao:ZE1.Institutional.Fact	crm:E5.Event	“This property is used to indicate an event context which limits the temporal scope within which an instance of institutional fact is meant to hold. When indicated the event context stands as the frame in which the institutional fact is held to be valid by the associated group for whom it has significance.” (54)
aaao:ZP4.holds_for	aaao:ZE1.Institutional.Fact	crm:E74.Group	“This property is used to indicate the community or group for whom an instance of institutional fact holds. Institutional facts have identity only relative to some group for whom they have a significance as formulated through a chosen symbolic system.” (54)
rss:has Unifying Factor	dul:Collection	owl:Thing	Property relating a collection to the recognizable patterns shared by all the members of a series, unifying them. For a more detailed description, see (41)
res:hasTime Period	res:Recurrent EventSeries	res:TimePeriod	Property relating a recurrent event series to the time frequency with which it occurs. (42)
:hasContext	crm:E1.Entity	:Historical Frame	Property defined in the Historical Frame module to relate the observed object, or the situations and events in which it appears, to a Historical Frame. In this context, it is reused to express the frame in which the function status is considered being valid, in a broader sense than the property aaao:Z75_applies_for_context, as it does not force to specify a specific event in which the function occurs.

1 Furthermore, the property :motivates serves to underline the influence of particular cultural traits or events on other objects.

2

3

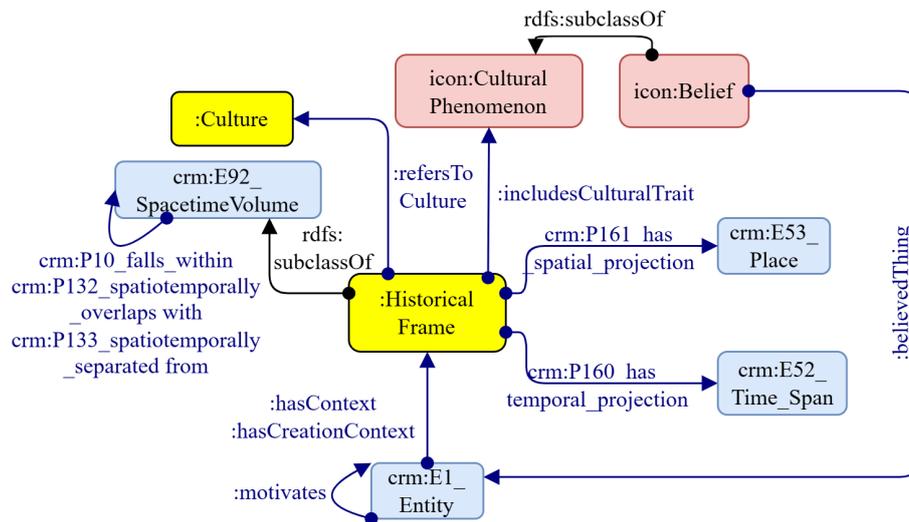


Figure 14. Module extending CIDOC-CRM and ICON to represent an historical observation Frame which put in relation observed CH objects with immaterial, socio-cultural aspects coexisting in spacetime and influencing the object.

1 The proposed modeling allows us to frame the context(s)
 2 of the CH object with different levels of granularity
 3 (requirement 2.4). For instance, the Historical Frame can
 4 identify periods in which cultural traits are recognized
 5 over long periods of time such as the religious culture
 6 of Maastricht from the Middle Ages till today. However,
 7 the Historical Frame can also be subdivided into smaller
 8 ones. These subdivisions allow for grouping more specific
 9 aspects of the culture in that period, such as the mentioned
 10 ephemeral expressions in Maastricht in the year 1962. Such
 11 smaller frames may include specific cultural traits and events
 12 that are not necessarily represented in the larger historical
 13 frame. In this way, the historical frame reflects two of the
 14 three types of observations defined in the GA storyline
 15 model (15) presented in 5.3. Historical Frames with a long
 16 duration over time and space (e.g., the Frame observing
 17 the culture of Maastricht from the 14th Century to today)
 18 combine the contextual traits that are always true for the
 19 whole considered period. The Historical Frame in this form
 20 is a kaleidoscopic view over the storylines of the objects
 21 and their contextual immaterial features (e.g., devotion for
 22 the Chest of Distress). At the same time, the relationship
 23 `crm:P10_falls_within` allows one to identify shorter
 24 periods. They can be observed in a 2D, synchronous view of
 25 a specific moment in time (e.g., the slice of spacetime of the
 26 procession in Maastricht in 1962).

27 Furthermore, single separated frames, or on the contrary,
 28 multiple overlapping frames can be recognized. For example,
 29 the historical frames of the thematic processions that
 30 occur uniquely include special features (e.g., temporary
 31 constructions, plays written for the occasion) that vary from
 32 theme to theme. Such frames do not overlap with each other
 33 but fall within the overall frame of the culture of Maastricht,
 34 in which the recurrent traits of the Chest's procession are
 35 also included. Cultural events can also be observed in a wide
 36 overlapping frame that encompasses separate frames such
 37 as the alternate use of liturgical objects by two completely
 38 different religious communities (e.g. the Catholic and the
 39 Protestant ones, in the same place and period)²³.

Historical Frames must not be confused with Reference
 Frames. The latter deal with common sense pre-knowledge
 used by the observing agent. This resembles the definition
 of `dul:Description`. This definition also represents the
 background knowledge of the observer in interpreting the
 object. This knowledge can be very generic but also very
 detailed, for instance, when dealing with interpretations of
 an expert based on domain knowledge.

8.3 Module 3: Evolution of material and immaterial objects and their functions

The module to express the evolution of material and imma-
 terial objects and their functions (group of requirements R3)
 combines AAAo with CIDOC-CRM and GA Storylines. It
 describes three types of evolution, namely the evolution in
 function and in the material and immaterial aspects of the
 object in question (Figure 15 and Tables 8 and 9).

To represent the change of function, the class
`aaao:ZE5_Function_Status`, introduced in
 module 8.1, is reused. Being defined as a temporal
 entity, the evolution of the function can be expressed
 by declaring multiple instances of the class. Each
 instance can be associated with a different time-
 span. The instances are indicated by the chronological
 order in which they occur through the relation
`aaao:ZP113_has_successor_status` (Requirement
 R3.1).

The physical evolution of the cultural object
 is represented by reusing and extending CIDOC-
 CRM. The activities determining a physical change
 of the object are already addressed by the model,
 namely: `crm:E11_Modification` and the
 subclasses part addition (`crm:E79`) and part removal
 (`crm:E80`). E79 and E80 indicate that a physical
 part that was added or removed from the object
 (respectively, through the relations `crm:P111` added
 and `crm:P113` removed), augments or diminishes
 (`crm:P110_augmented/crm:P112_diminished`)
 the same object, without changing its identity. For this
 reason, the intervention does not create a new instance

Table 6. Classes of the Historical Frame module (Module 2)

Class	Description
Newly added classes	
<code>:HistoricalFrame</code> subclass of <code>crm:E92_SpacetimeVolume</code> <code>:Culture</code> <code>owl:sameAs</code> <code>sdhss:C26</code> <code>Representation</code>	The Historical Frame captures the space-time continuum to relate the observed CH object(s) to socio-cultural characteristics of the same context(s). It captures a portion of spacetime in which the CH object coexisted with immaterial, cultural traits that interacted with them. Fuzzy class to indicate the broad concept of culture of which the frame observes some features (e.g., Belief that St. Servatius drunk from the drinking cup)
Reused classes	
<code>crm:E53_Place</code>	"This class comprises extents in the natural space where people live [...] They may serve describing the physical location of things or phenomena or other areas of interest." (56)
<code>crm:E52_Time_Span</code>	Abstract temporal extents, having a beginning, an end, and a duration. No semantic connotations are attributed to them.
<code>icon:CulturalPhenomenon</code>	"The cultural phenomenon entity expresses the cultural, social, and historical aspects of which the work of art can be a document." (56)
<code>icon:Belief</code>	Specification of a cultural phenomenon as a belief
<code>icon:Attitude</code>	Specification of a cultural phenomenon as an attitude
<code>icon:CulturalValue</code>	Specification of a cultural phenomenon as a cultural value
<code>icon:Tendency</code>	Specification of a cultural phenomenon as a tendency

Table 7. Properties of the Historical Frame module (Module 2)

Property	Description
Newly added Properties	
<code>:hasContext</code>	<code>crm:El_Entity</code> <code>:HistoricalFrame</code> Relation between objects, events or situations in which they participate, and a <code>:HistoricalFrame</code> which identifies the socio-cultural context in which the object existed
<code>:hasCreationContext</code>	<code>crm:El_Entity</code> <code>:HistoricalFrame</code> Subproperty of <code>:hasContext</code> to specifically express that the object examined is related to the cultural context in which it was created (e.g., "Roman culture" is the creation context of the Roman cup created in I Century)
<code>:includesculturalTrait</code>	<code>:HistoricalFrame</code> <code>icon:CulturalPhenomenon</code> The property relates a Historical Frame with the immaterial traits of a culture that are relevant for the understanding of the objects.
<code>:refersToCulture</code>	<code>:HistoricalFrame</code> <code>:Culture</code> Relation of historical frame to the fuzzy culture it observes
<code>:motivates</code>	<code>crm:El_Entity</code> <code>crm:El_Entity</code> Generic relation that expresses that an entity motivates the existence or characteristics of another one (e.g., the belief that St. Servatius drunk from the cup motivates the healing function of the cup)
<code>:believedThing</code>	<code>icon:Belief</code> <code>crm:El_Entity</code> A relation specifying the thing believed in the belief system of the culture in question.
Reused properties	
<code>crm:P10_falls_within</code>	<code>crm:E92_SpacetimeVolume</code> <code>crm:E92_SpacetimeVolume</code> "This property associates an instance of E92 Spacetime Volume with another instance of E92 Spacetime Volume that falls within the latter. In other words, all points in the former are also points in the latter. This property is transitive and reflexive" (56)
<code>crm:P132_spatiotemporally_overlaps_with</code>	<code>crm:E92_SpacetimeVolume</code> <code>crm:E92_SpacetimeVolume</code> "This symmetric property associates two instances of E92 Spacetime Volume that have some of their extents in common" (56)
<code>crm:P133_spatiotemporally_separated_from</code>	<code>crm:E92_SpacetimeVolume</code> <code>crm:E92_SpacetimeVolume</code> "This symmetric property associates two instances of E92 Spacetime Volume that have no extents in common" (56)
<code>crm:P161_has_spatial_projection</code>	<code>crm:E92_SpacetimeVolume</code> <code>crm:E53_Place</code> "This property associates an instance of E92 Spacetime Volume with an instance of E53 Place that is the result of the spatial projection of the instance of the E92 Spacetime Volume on a reference space" (56)
<code>crm:P160_has_temporal_projection</code>	<code>crm:E92_SpacetimeVolume</code> <code>crm:E52_Time_Span</code> "This property describes the temporal projection of an instance of E92 Spacetime Volume" (56)

of the object²⁴. As a consequence, CIDOC-CRM does not provide a solution for modeling different versions of the object when its identity is preserved. This is because modifications (parts addition and removal) act on the same instance. To solve this problem and to allow for the identification of different versions, the property `:manifestsIn` is newly introduced. It relates the same physical object to multiple physical versions of it. This

makes it possible to provide more details for each version (e.g., corresponding immaterial versions) as proposed in a previous study (40). Furthermore, we introduce the property `:createsPhysicalVersion` that indicates the version of the object created after the physical intervention.

Nevertheless, an extension is needed to register immaterial changes that affect the immaterial part of the object, namely, the visual representation (`crm:E36`

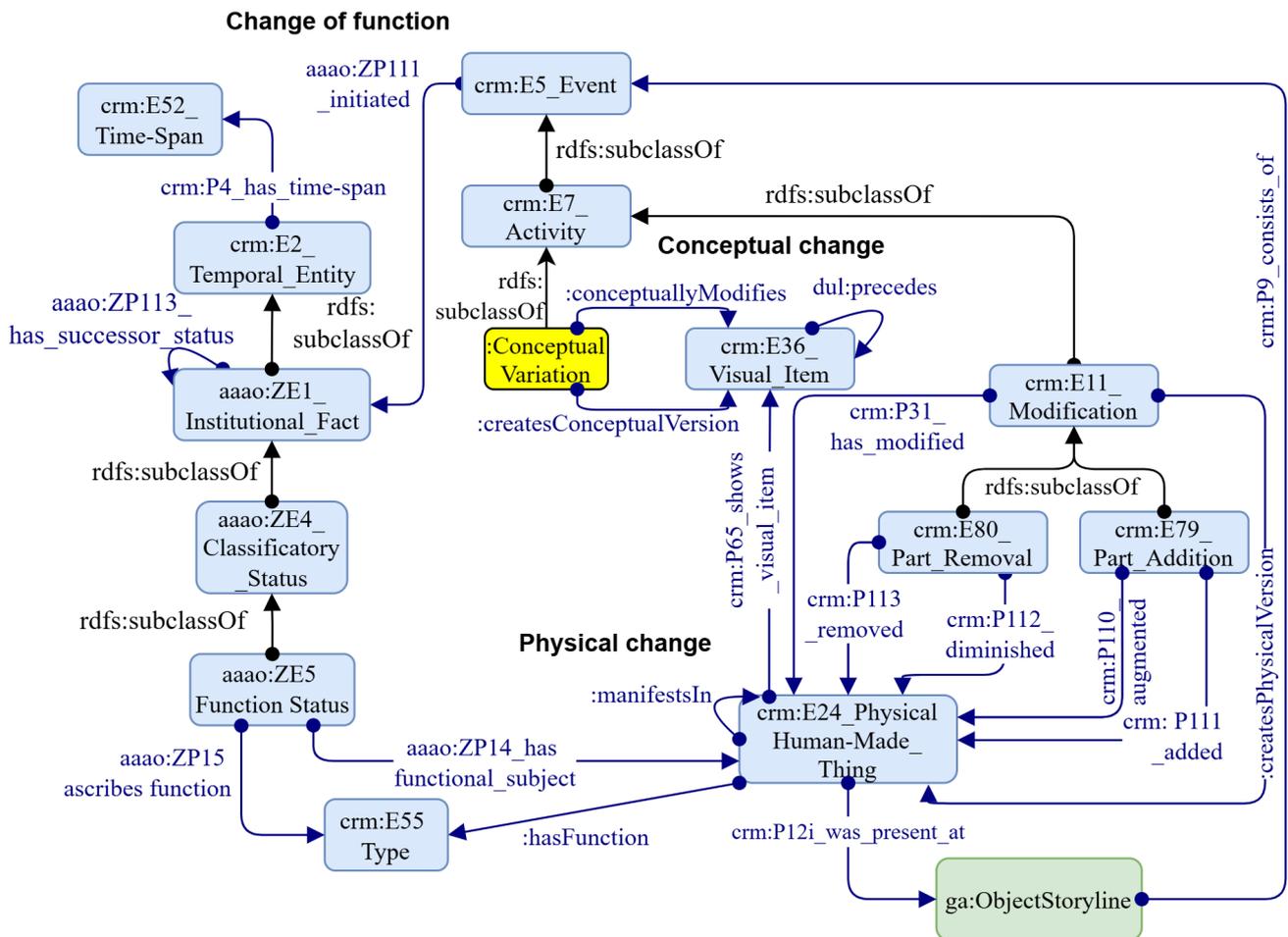


Figure 15. Module to describe the evolution of the functions of the object and its material and immaterial aspects

1 Visual Item). CIDOC-CRM provides only the class
 2 `crm:E65_Creation` to indicate an activity that leads
 3 to the creation of a conceptual item. However, such class
 4 implies that there is no continuity in the identity of the object,
 5 similarly to the `E81_Transformation` class described
 6 above. To solve this problem and to provide a versioning
 7 of the visual, immaterial stages of the CH object, a class
 8 `:ConceptualVariation` is introduced, modifying
 9 (`:conceptuallyModifies`) a previous version and
 10 creating a new one (`:createsConceptualVersion`),
 11 as a subclass of `crm:E7_Activity`. Being subclasses of
 12 `crm:E5_Event`, the physical interventions described above
 13 and the `:ConceptualVariation` can be indicated as
 14 those activities initiating a new functional status through the
 15 property `aaa:ZP111_initiated` (requirement R3.2).
 16 The property `dul:precedes` is reused to indicate the
 17 sequence in which the two Visual Items occur. As a Visual
 18 Item is not a temporal entity, there is no available property in
 19 CIDOC-CRM to indicate an order between these two items.
 20 Instead, this is addressed by the reused DOLCE property.

21 In this way, CIDOC-CRM's domain-specific representa-
 22 tions of modifications of CH can be combined with the
 23 AAAo description of a function status to describe both
 24 (im)material and functional changes of a CH by proposing
 25 a minimal extension only.

26 The evolution of material and immaterial variations of
 27 the object can be modeled by reusing the GA model

of storylines (15) (requirement R3.1). The storyline is
 28 defined herein as a chain of events (perdurants) in which
 29 the observed CH object participates. Although not yet
 30 formalized in OWL (see future work), the model is
 31 reused here to trace the temporal evolution of objects. As
 32 storylines can encompass all objects that have a persistent
 33 identity throughout time (i.e., endurants), all material and
 34 immaterial entities can be included in a storyline by
 35 reusing the relation `crm:P12i_was_present_at`. The
 36 same applies to the events in which the object participates,
 37 corresponding, in the proposed module, to the subclasses of
 38 `crm:E7_Activity` (i.e., `:ConceptualVariation`,
 39 `crm:E79`, `crm:E80`, `crm:E81`), for which the property
 40 `crm:P9_consists_of` is used²⁵.
 41

42 Nevertheless, some issues arise when aligning
 43 `aaa:ZE5_Function_Status` to the model. In fact,
 44 both the storylines and the views traversing it are defined
 45 as perdurants. In CIDOC-CRM, only `E5_Event` and its
 46 subclasses, are defined as perdurants. Institutional Facts
 47 (`aaa:ZE1`) and its subclasses, including `Function`
 48 `Status`, are declared as temporal entities `crm:E2`, and
 49 not specifically as events. Therefore they do not explicitly
 50 comply with the definition of perdurant as provided by
 51 CIDOC-CRM. For this reason, more research is needed to
 52 fully understand the implications of reusing storylines as a
 53 complex object composed of statuses in which the object
 54 acquires different functions. This is left for future work.

Table 8. Newly added classes and properties of the Evolution module (Module 3)

Class	Description
Newly added classes	
:ConceptualVariation subclass of crm:E7_Activity	The class identifies an activity that modifies immaterial visual traits of a CH object, such as the subject depicted, creating two versions of the immaterial object, which correspond to the version preceding the intervention and the one resulting from it.
Reused classes	
aaao:ZE5_Function Status crm:E52_Time-Span	See the definition provided in Table 4
crm:E5_Event	“This class comprises abstract temporal extents, in the sense of Galilean physics, having a beginning, an end, and a duration.”(56)
crm:E36_Visual_Item	see the definition provided in Table 4
crm:E11_Modification	“This class comprises the intellectual or conceptual aspects of recognisable marks, images and other visual works” (56)
crm:E80_Part_Removal subclass of	“This class comprises instances of E7 Activity that are undertaken to create, alter or change instances of E24 Physical Human-Made Thing” (56)
crm:E11_Modification crm:E79_Part_Addition subclass of	“This class comprises the activities that result in an instance of E18 Physical Thing being decreased by the removal of a part” (56)
crm:E11_Modification crm:E24_Physical_Human- Made_Thing	“This class comprises activities that result in an instance of E18 Physical Thing being increased, enlarged or augmented by the addition of a part” (56)
crm:E55_Type	“This class comprises all persistent physical items of any size that are purposely created by human activity” (56)
ga:Storyline	“This class comprises concepts denoted by terms from thesauri and controlled vocabularies used to characterize and classify instances of CIDOC CRM classes” (56)
	“Storyline is a UFO:ComplexEvent that can be split into (i) ga:Object-Storyline, which is composed of participations of a single UFO:Object, and (ii) ga:Bundle-Storyline (Kublers’ “fibers of duration”), in which two or more UFO:Objects participate.” See the UML model of Storylines defined in (15)

8.4 Module 4: Ephemeral in Tangible and Intangible Cultural Heritage

Whereas historical frames allow for observing objects in situations or storylines in distinct event types based on frequencies in duration, ephemeral events are far more fluid and fuzzier.

This module describes how some characteristics of ephemeral events can be captured (group of requirements R4). It reuses existing models without proposing new classes or properties, as the requirements can be already satisfied by state-of-the-art solutions. This can be done by reusing the class `crm:E5_Event` and `crm:E52_Time-Span` in combination with the representation of time according to the Extended Date/Time Format (EDTF) specification, the Time Ontology, and the Getty AAT vocabulary (see Figure 16).

In CIDOC-CRM, the class `E5_Event` represents “defined and coherent processes and interactions of a material nature, in cultural, social, or physical systems”, in which the constituents “contribute to an overall effect”. However, they are not required to produce permanent changes to the objects in question. Some examples given in the documentation are statements made during meetings and performances. As `E5_Events` may or may not influence the properties of participants and can be specified with fuzzy time intervals, they are feasible to represent the ephemeral events included in this study. They are intended as 1) events of short duration with no specific beginning or end (e.g., the swinging of the scent thuribles in the procession), 2) events as part of immaterial CH, such as processions and thematic events related to it, which do not survive through time unless they are documented, 3) instant decisions having permanent

effects on the CH objects (e.g., the decision to restore the Chest of Distress without the votive heads).

Indeed, the duration of a temporal entity can be expressed through a `crm:E52_Time-Span` class, representing abstract temporal extents. Although it is supposed to include a start, an end and a duration, the approximation inherent in our knowledge about historical phenomena, which are fuzzy in nature, is acknowledged in the model. Consequently, `E52` classes with unknown time specifications are allowed (56, p. 86). The relations `crm:P79_beginning_is_qualified_by` and `crm:P80_end_is_qualified_by` can be used to express, in the form of a string, the extreme boundaries of the time span. It should be noted that `E52_Time-Span` does not express a computable time interval itself, but a description of the time extent of an observed phenomenon. Therefore, when information about the start, end, or duration of an event is present, even in a fuzzy format, it can be expressed through reusing the Time Ontology, which defines computable time indications. Through it, the `time:Instant` defining the start or the end of a period can be represented, and the `time:Duration` can be related to an `E52` instance with a relation of approximation, indicating the maximum (`crm:P82_at_some_time_within`) and minimum (`crm:P81_ongoing_throughout`) duration of the interval. In case the exact time is not known or uncertain, the time values can be expressed through the EDTF Specification as implemented in the EDTF Ontology (requirement R4.2). In particular, the qualifiers “?”, “~” and “%” are included in the string indicating a date to mean “uncertain” (e.g., “1540?”), “approximate” (e.g., “1540~”), and “uncertain” or “approximate” (e.g., “1540%”), are particularly useful in the context of the description of uncertainty related to

Table 9. Properties of the Evolution module (Module 3)

Property	Domain	Range	Description
Newly added properties			
:conceptually Modifies	:Conceptual Variation	crm:E36.Visual _Item	The property relates the :ConceptualVariation to the Visual Item it modifies, i.e., the version of the work before the intervention
:createsConceptual Version	:Conceptual Variation	crm:E36.Visual _Item	The property relates the :ConceptualVariation to the Visual Item version resulting from the intervention
:createsPhysical Version	crm:E11 _Modification	crm:E24.Physical _human_made_Thing	The property relates the crm:E11.Modification to the physical version resulting from the intervention
:manifestsIn	crm:E24. Physical _human_made _Thing	crm:E24. Physical _human_made _Thing	The property relates a CH artifact to the physical versions that are created by a physical act that consistently modifies the artifact but without affecting its identity. It is the result of the action of a crm:E11.Modification that generates a new version of the item (and not a fully new item).
Reused properties			
aaao:ZP113.has_ successor_status	aaao:ZE1. Institutional_Fact	aaao:ZE1. Institutional _Fact	"This property links one instance of institutional fact with another where the latter succeeds the former as a formal continuation."
aaao:ZP111.initiated	crm:E5.Event	aaao:ZE1. Institutional_Fact	"This property is used to connect the instance of event to the instance of institutional fact which it brought into existence by fiat thanks to its accordance to a socially defined norm."
dul:precedes	dul:Entity	dul:Entity	"A relation between entities, expressing a 'sequence' schema"
crm:P65.shows _visual_item	crm:E24.Physical _Human-Made_Thing	crm:E36.Visual _Item	This property documents an instance of E36 Visual Item shown by an instance of E24 Physical Human-Made Thing. In the current model, it is used to relate the physical part of the object to the immaterial, visual one.
crm:P31.has_modified	crm:E11. Modification	crm:E18.Physical _Thing	"This property identifies the instance of E18 Physical Thing modified in an instance of E11 Modification." It is superproperty of crm:P110_augmented and crm:P112_diminished.
crm:P110_augmented	crm:E79.Part _Addition	crm:E18.Physical _Thing	"This property identifies the instance of E24 Physical Human-Made Thing that is added to (augmented) in an instance of E79 Part Addition"
crm:P113.removed	crm:E80.Part _Removal	crm:E18.Physical _Thing	"This property identifies the instance of E18 Physical Thing that is removed during an instance of E80 Part Removal activity." It is subproperty of crm:P112_diminished.
crm:P112_ diminished	crm:E80.Part _Removal	crm:E18.Physical _Thing	"This property identifies the instance of E18 Physical Thing that was diminished by an instance of E80 Part Removal."
crm:P111.added	crm:E79.Part _Addition	crm:E18.Physical _Thing	"This property identifies the instance of E18 Physical Thing that is added during an instance of E79 Part Addition activity"
crm:P12i. was_present_at	crm:E77.Persistent _Item	crm:E5.Event	"This property describes the active or passive presence of an E77 Persistent Item in an instance of E5 Event without implying any specific role." In this context, it is reused to indicate the participation of an object (endurant) in a storyline (perdurant).
crm:P4.has _time-span	crm:E2.Temporal _Entity	crm:E52.Time-Span	"This property associates an instance of E2 Temporal Entity with the instance of E52 Time-Span during which it was on-going".

ephemeral events. Furthermore, periods having an unknown beginning or end can be specified through an empty string (e.g. "'1540/"), and periods having an open start or end are represented with two dots (e.g. "'1540/."). The EDTF ontology is needed as the specification is not compatible with the XSD time format used by the Time Ontology and the standard for RDF data (43) (see Section 4.4).

As for many ephemeral events, a start or end is not known, qualitative relations between time entities are fundamental to establish the sequence in which they occur (requirement R4.3). As suggested in (15), Allen's property can be used for this purpose. This is implemented in the Time Ontology. Whereas multiple types of relation within time entities exist, the `time:before` and `time:after` properties are reported.

Nevertheless, the general scope of the class `E5 Event` that includes, for instance, the creation of a poem makes it still difficult to distinguish ephemeral events from other

spatiotemporal events (requirement R4.1). For this reason, this paper suggests including a `crm:E55_Type` that specifies events and objects as ephemeral through the use of terms from controlled vocabularies. Specific types of ephemeral events and experiences, including odors, can be described using the Odeuropa data model. As the model is aligned with CIDOC-CRM, a `od:L12_Smell_Emission` can fall within the event in which it may take place. The smell generated by the action (`od:L11_Smell`) can then be further specified with the specific olfactory experience (`od:L13`).

As explained in Section 2, the concept of ephemerality is used in relation to objects that are intentionally created to be temporary in the art history domain (requirement R4.1). For this reason, it is suggested to use `crm:E55_Type` combined with the available terms for the description of ephemeral provided by the Getty Art and Architecture

1 Thesaurus (AAT), which includes descriptors for ephemeral
2 art and architecture.

3 9 The Case Study in Models

4 In Section 6.1, five types of interactions were described
5 between tangible and intangible CH. Furthermore, it was
6 explained how historical events and objects related to the cult
7 of St. Servatius could be analyzed in historical frames. This
8 was done with the intention of getting a better understanding
9 of changes in the use and meaning of CH objects in context
10 over time. These five types of interaction are discussed here
11 in more detail in ontological models through the modules
12 proposed in Section 8.

13 9.1 Interactions between tangible and 14 intangible cultural heritage in regular 15 recurrent events of long duration and 16 ephemeral events

17 *Historical frames.* A `:HistoricalFrame` of long dura-
18 tion, “Culture religious, popular culture of Maastricht 14th
19 C. Today” identifies the essence of the immaterial culture
20 characterized by persisting traits of worship related to the
21 veneration of the saint and the recurrent processions (see
22 module 2 and Figure 17). The culture to which it per-
23 tains is represented by the class `:Culture`, related to the
24 frame through a `:refersToCulture` property. The class
25 `:ObjectInRecurrentRegularEvent` represents the
26 series of recurring events “Chest of Distress in pilgrim-
27 age procession”, belonging to this culture, as well as the
28 `icon:CulturalPhenomenon` “devotion for the Chest
29 of Distress”. Nevertheless, smaller parts of the spacetime
30 volume can be identified for closer exploration. For example,
31 the frame identifying the culture in 1962, falling within
32 (`crm:P10_falls_within`) the previous frame, refers to
33 the slice in spacetime occurring in that year. Both frames
34 are related, respectively, to `crm:E52_Time-Span` and to
35 the city of Maastricht (`crm:E53 Place`) through the rela-
36 tions inherited from the superclass `crm:E92 Spacetime`
37 `Volume`, respectively, `crm:P160` has temporal projec-
38 tion and `crm:P161` has spatial projection. As the former
39 timespan presents characteristics of indeterminacy, it is fur-
40 ther described with EDTF time specifications, as defined
41 in Module 4. To this aim, a `time:Interval` instance
42 is related to the period from circa 1409, in which the
43 indeterminacy of the date attribution is indicated by a
44 “?”, to today, constituting an open period represented by
45 two dots. The relation is established through the property
46 `edtf:hasEDTFDateTimeDescription`, which pro-
47 vides a mapping between the EDTF specification and the
48 XSD times expressed by the Time Ontology.

49 *Recurrent events.* Recurrent events can be modeled
50 through the `:ObjectInRecurrentRegularEvent`
51 class, defined in Section 8.1. This identifies events that
52 are planned to occur regularly in time. The class includes
53 (`dul:includesObject`) the Chest of Distress and
54 further unifying factors (`rss:hasUnifyingFactor`),
55 such as the city of Maastricht (`crm:E53`) and the train of
56 relic holders (`crm:E74 Group`). Two time intervals during
57 which the procession regularly occurred are represented

58 through `time:Interval`. These are further described by
59 the EDTF time specification to include the features of an
60 open period (from 1874 to today, represented by two dots)
61 and an uncertainty in the date attribution (“1517”).

62 *Specific events and ephemeral objects.* Following the
63 Recurrent Situation Series ODP, the recurrent event class is
64 related to specific events which are making part of it through
65 the relation `:hasMemberEvent`. In this way, specific
66 aspects of single events can be modeled. An example is
67 the Septennial Pilgrimage Procession of 1962 which had the
68 specific theme: “Proclaiming the Riches of Christ”. The artist
69 Jérôme Goffin designed clothing and temporary, ephemeral
70 structures and installations for this single event.

71 The traits can be modeled with CIDOC, indicating that
72 the E12 Production of every object made use of the
73 design (`crm:P33_used_specific_technique`,
74 `crm:E29_Design_or_Procedure`) created by
75 Jérôme Goffin (`crm:E65_Creation`, related to the
76 author and the timespan). A drawing (see Figure 5)
77 depicts (`crm:P62_depicts`) the thematic design.
78 The property `crm:P129_is_about` relates the
79 design to the theme, represented by an instance of
80 `crm:E89_Propositional_Object`.

81 The objects, which have an ephemeral nature, as they are
82 intended to be used only for that occasion, are specified
83 as ephemeral through the relation `crm:P2_has_type`,
84 identifying the AAT term “temporary buildings” and
85 “ephemeral”.

86 The event identifying the procession consists of
87 (`crm:P9`) a more specific activity, namely the swinging of
88 thuribles, which create the olfactory experience of the scent
89 of incense, modeled through the Odeuropa ontology (48).

90 9.2 Interactions between tangible and 91 intangible cultural heritage in irregular 92 recurrent events and ephemeral events

93 In the popular culture of Maastricht, there are cultural
94 practices that do not recur regularly over time, but
95 have a specific meaning and function. The Chest of
96 Distress is brought out and carried through the streets of
97 Maastricht to protect its inhabitants in times of danger.
98 Although a regular interval cannot be defined, the act
99 acquires a particular function and meaning, based on
100 defined unifying characteristics at these occasions. In this
101 section, the irregular recurrent event of the Chest brought
102 out of the basilica on these occasions is represented
103 (see Figure 18). The observed object, i.e., the Chest, is
104 related to the `ObjectInRecurrentIrregularEvent`
105 class, which represents the collection of events presenting
106 the same characteristics. The property `:includesFact`
107 relates the object to the function status it has in the
108 recurrent events (in this case the function of protection
109 by the Chest when brought in procession). The relation
110 `:includesEventsOfType` declares the constant type
111 that these events in the pattern have (e.g., a public
112 procession). As the Object in the Recurrent Event class
113 is a subclass of `dul:Situation`, the pre-knowledge
114 reference Frame (see Section 5.1) allows the identification
115 of the function of the Chest to be expressed through a
116 `dul:Description`.

Table 11. Reused properties of the Ephemeral module (Module 4)

Property	Domain	Range	Description
crm:P4_has_time-span	crm:E2_Temporal _Entity	crm:E52_Time-Span	See the definition provided in Table 9
crm:P82_at_some _time_within	crm:E52_Time-Span	crm:E61_Time _Primitive	"This property describes the maximum period of time within which an E52 Time-Span falls."
crm:P81_ongoing _throughout	crm:E52_Time-Span	crm:E61_Time _Primitive	"This property associates an instance of E52 Time-Span with an instance of E61 Time Primitive specifying a minimum period of time covered by it."
crm:P79_beginning _is_qualified_by	crm:E52_Time-Span	crm:E62	"This property associates an instance of E52 Time-Span with a note detailing the scholarly or scientific opinions and justifications about the certainty, precision, sources etc. of its beginning."
crm:P80_end_is _qualified_by	crm:E52_Time-Span	crm:E62	"This property associates an instance of E52 Time-Span with a note detailing the scholarly or scientific opinions and justifications about the end of this time-span concerning certainty, precision, sources etc."
crm:P11_had _participant	crm:E5_Event	crm:E39_Actor	"This property describes the active or passive participation of instances of E39 Actors in an instance of E5 Event."
crm:P2_has_type	crm:E1_Entity	crm:E55_Type	"This property allows sub typing of CIDOC CRM entities –a form of specialisation – through the use of a terminological hierarchy, or thesaurus"
crm:P10_falls_within	crm:E92_Spacetime _Volume	crm:E92_Spacetime _Volume	"This property associates an instance of E92 Spacetime Volume with another instance of E92 Spacetime Volume that falls within the latter. In other words, all points in the former are also points in the latter"
time:before	time:Temporal Entity	time:Temporal Entity	"Gives directionality to time. If a temporal entity T1 is before another temporal entity T2, then the end of T1 is before the beginning of T2."
time:after	time:Temporal Entity	time:Temporal Entity	"Gives directionality to time. If a temporal entity T1 is after another temporal entity T2, then the beginning of T1 is after the end of T2."
time:hasEnd	time:Temporal Entity	time:Instant	"End of a temporal entity"
time:hasBeginning	time:Temporal Entity	time:Instant	"Beginning of a temporal entity"
edtf:hasEDTFDate TimeDescription	time:TimeInterval	EDTF datatype	"Value of an interval, expressed using EDTF"
od:F1_generated	od:L2_Stimulus _Generation	od:L1_Sensory _Stimulus	"This property associates an instance of L2 Stimulus Generation with the L1 Sensory Stimulus which was created by the event."
od:F2_perceived	od:L3_Sensory _Experience	od:L1_Sensory _Stimulus	"This property associates an instance of L3 Sensory Experience with the L1 Sensory Stimulus which was experienced"
od:F6_evoked	od:L3_Sensory _Experience		"This property associates an instance of L3 Sensory Experience with a (material or conceptual) entity which is evoked during the experience itself. This includes memories of people or situations, comparison to similar stimuli, references, etc"

1 the chest. For this reason, two classes identifying the
2 votive (:SocialFunction) and the esthetic functions
3 (:PracticalFunction), are respectively related to
4 the votives (crm:E22) and the gemstones (crm:E22)
5 through the relation :hasFunction. As illustrated above,
6 the evolution module 8.3 can be applied in this case
7 study to express that the physical interventions initiated
8 (aaa:ZP111) has a new function status (aaa:ZE5). It
9 identifies the prominent esthetic function of the Chest, which
10 comes after (aaa:ZP113_has_successor_status) a
11 previous status, which represents the social-religious votive
12 function that the object had before the restoration. In this
13 way, a relation between the material changes of the object
14 and the contextual activities that cause them is registered.

15 *Historical Frames.* To indicate to which cultural context
16 the actions belong, four historical frames are specified.
17 The first one identifies the religious and popular culture of
18 Maastricht from the 14th century to today. It is characterized
19 by an icon:CulturalPhenomenon, in this case, the
20 devotion to the Chest of Distress. A smaller frame, part of
21 it (crm:P10_falls_within) indicates the state of affairs
22 present in 1450 ca., which is the context of the addition

of the votives. Another frame, which overlaps with the
first one (crm:P132 spatiotemporally overlaps
with), indicates the belief system of the group of experts
that guided the restoration in the years 1958-1962. It includes
the icon:CulturalValue of values such as the esthetic
features of the CH artifacts. Such a frame could be seen, for
instance, as a slice of a fourth frame of Western restoration
practices applied in the twentieth century.

31 *Storyline.* A ga:ObjectStoryline of the Chest
32 of Distress collects all the events in which it partici-
33 pates (crm:P12i_was_present_at). Being perdu-
34 rants, physical restoration interventions of part addi-
35 tion and removal can be added to the storyline. Nev-
36 ertheless, for the problems of aligning a temporal
37 entity as defined in CIDOC-CRM with the Storyline
38 model, already discussed in Section 8.3, we do not
39 include the instances of aaa:ZE5_Function_Status
40 in ga:ObjectStoryline.

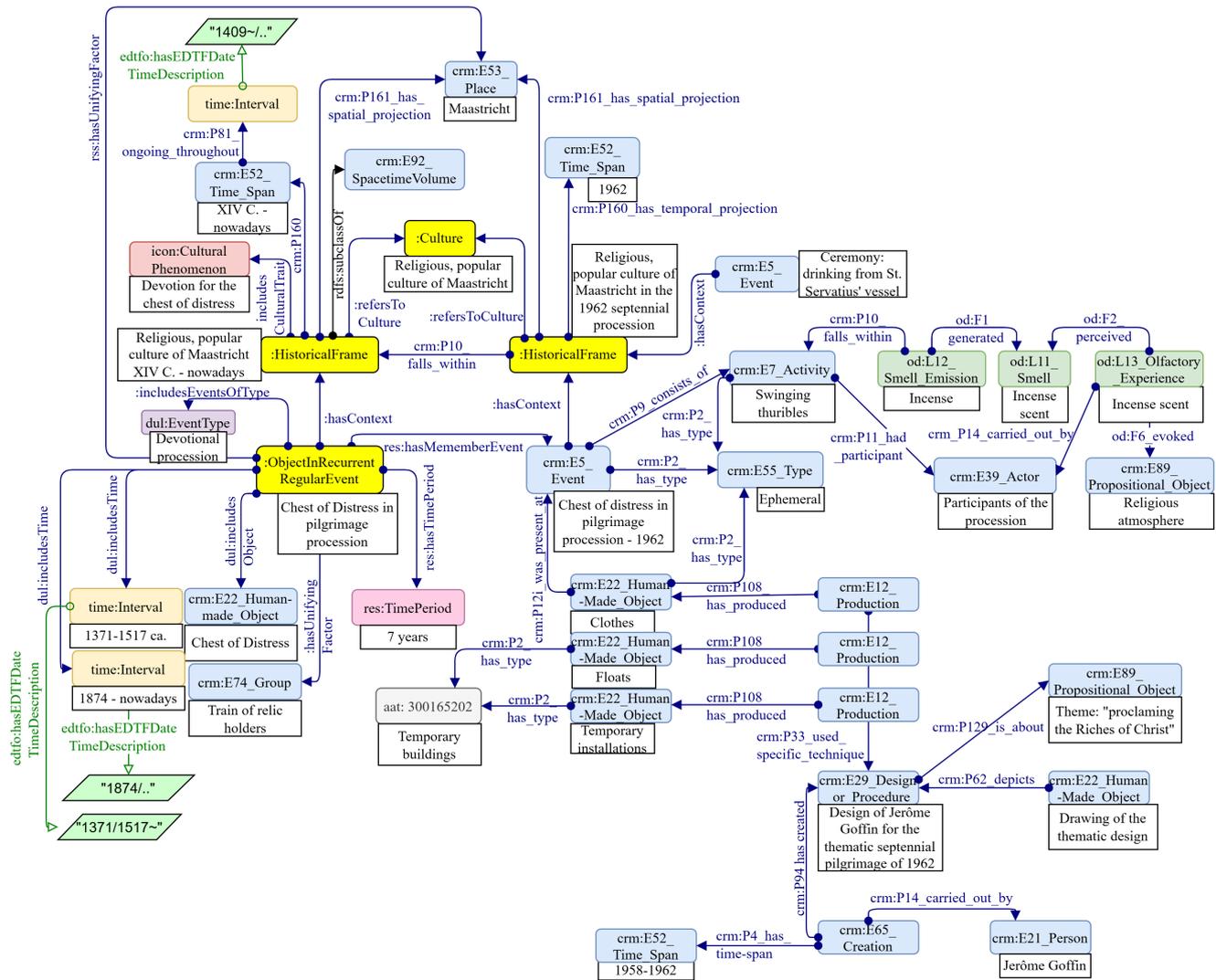


Figure 17. Modeling of the regular recurrent event of the Chest of Distress in pilgrimage procession, including the specific event of the 1962 procession (case 1)

9.4 Events in the restoration process of objects leading to changes in the iconographical meaning of CH objects in context

The event of the restoration of 1962, illustrated above, brought significant changes in the iconography and iconological meaning of the Chest. One of the most relevant variations concerns the scene on the short gable representing St. Servatius between angels. As described in Section 6.1, originally one of the angels was giving the bishop's staff to St. Servatius. This action was crucial in legitimizing the role of bishop acquired by the saint. It implied that this role was given to Servatius by God himself, via the intervention of the angel. As a consequence, the removal of the staff had a considerable impact on the symbolic message that it expressed.

In Figure 20, the specific scene in the gable on the short side is modeled as a feature (crm:E26_Feature) of the Chest. Similarly to the third case of interaction, the physical removal of the bishop's staff from the scene can be described as a crm:E80_Part_Removal performed by the group of experts and the restorer in 1962. It has as

context the frame of restoration practices in the years 1958-1962. In this example, the physical interventions caused a variation on the conceptual level of the object. Therefore, crm:E80_Part_Removal motivates (crm:P17i) a :ConceptualVariation instance, occurred in 1962, which :conceptuallyModifies and :creates ConceptualVersion two versions of the immaterial visual part of the item (crm:E36), related to the feature through the property crm:P65_shows_visual_item.

The relation dul:precedes indicates that the first one occurs in time before the second. Classes of the ICON ontology can signify the subjects and meanings represented in the CH object (crm:E36) before and after restoration. The previous CH object version depicts, at the second level of interpretation (icon:iconographicallyDepicts), the subjects of the bishop staff (icon:NamedObject), the angels and the saint (icon:Character), the action of the angel giving it to St. Servatius (icon:Event), and the symbolic reading of the gesture as God giving to St. Servatius the role of bishop (icon:Symbol). At the third level of interpretation (icon:iconologicallyRepresents) the icon:Belief that St. Servatius became a bishop by the will of God is acknowledged. This is in turn related to the

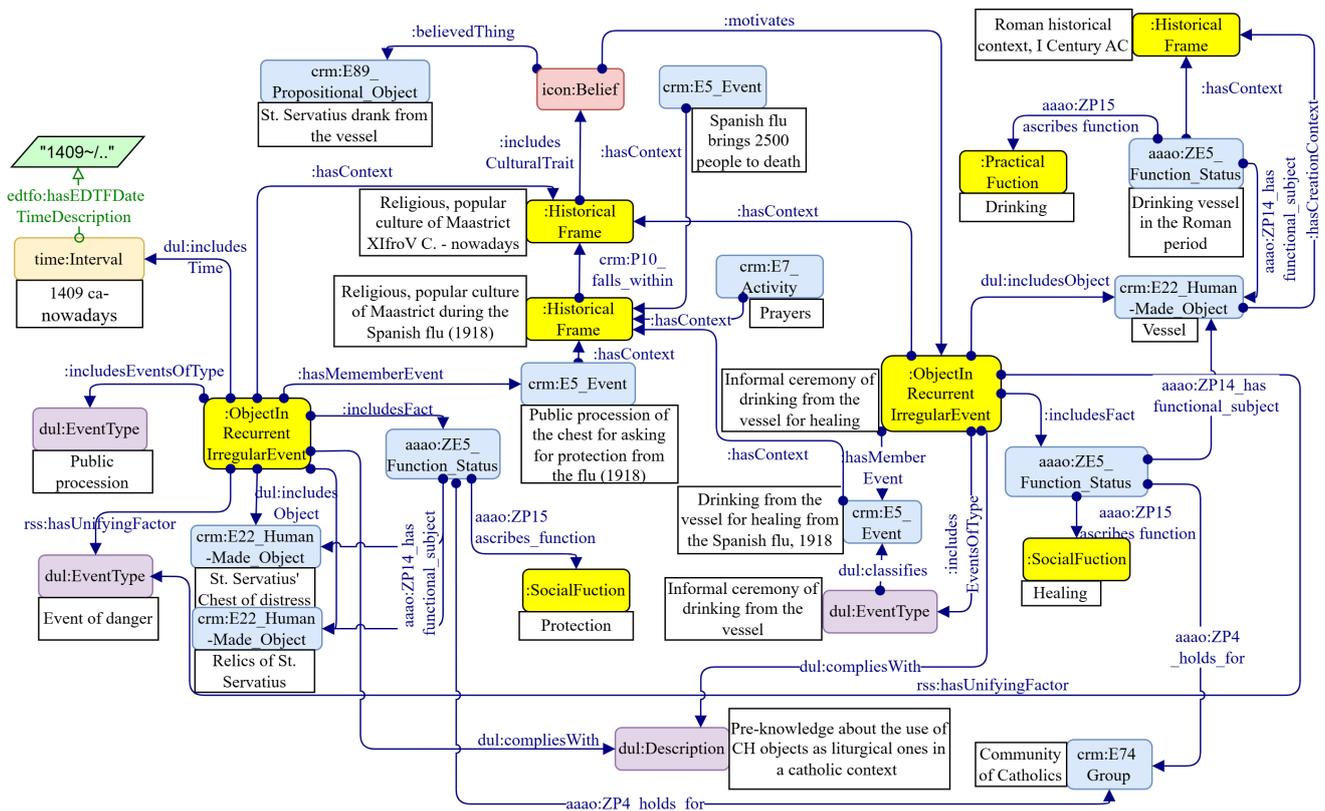


Figure 18. Modeling of the recurrent irregular events of procession of the Chest of Distress in cases of emergency (case 2) and the ceremony of drinking from St. Servatius’s vessel as a healing practice (case 5)

1 :HistoricalFrame of the culture of Maastricht. The
 2 loss of meaning is expressed by the fact that only the figures
 3 of St. Servatius and the angels are represented in the instance
 4 of the CH object after its restoration.

5 Both the immaterial (crm:E36) and material (crm:E22;
 6 crm:E26) parts of the CH object can be included in a
 7 Storyline. As the object is examined in its components, they
 8 participate in a ga:ComplexObjectStoryline.

9 9.5 Ephemeral events providing meaning to 10 material objects by immaterial practices

11 The last case of interaction presented here is the acquisition
 12 of meaning and function through the healing ritual of
 13 drinking from the St. Servatius cup illustrated in Section 6.

14 According to the belief (the event is not considered
 15 to be historical from a non-Catholic perspective due to
 16 inconsistencies in historical sources), St. Servatius drank
 17 from a cup, which was identified as the 1st-century AD
 18 Roman vessel discussed here. Hence, the Roman vessel,
 19 which originally had a sole practical function, obtained
 20 a new healing function in the religious context from the
 21 14th century onward. This meaning comes into being when
 22 believers drink from it, usually during an intimate ceremony.
 23 In this case, a believed fact had a long-lasting impact on the
 24 cup’s function in the upcoming centuries. One of the many
 25 occasions in which the drinking ceremony took place was
 26 during the Spanish flu of 1918 (Figure 18).

27 Such a recurring situation can be represented through an
 28 :ObjectInRecurrentIrregularEvent class, hav-
 29 ing as members the events in which it took place, e.g., the
 30 E5 Event of the ceremony that happened in 1918. This

situation includes events that have as a type “an informal
 31 ceremony of drinking from the vessel”, which defines the
 32 characteristics of the events involved. Whereas the recurrent
 33 event is related to the :HistoricalFrame of the religious,
 34 popular culture of Maastricht from the 14th century to today,
 35 the 1918 event is related to the Historical Frame of
 36 that specific year.

37 Furthermore, an instance of aaaa:ZE5_Function_
 38 Status relates the same object (namely, the vessel)
 39 with the drinking function (:PracticalFunction)
 40 it had in the Roman context. This is represented
 41 in another :HistoricalFrame instance, through the
 42 :hasCreationContext relation. It refers to the Roman
 43 context in which the object was created. The fact that
 44 the same object is related to two different situations, in
 45 turn associated with two historical frames having different
 46 spacetime coordinates, expresses the change of the vessel’s
 47 function in the two different contexts.

48 This modeling allows for relating a function to specific
 49 groups of events while identifying relevant cultural traits
 50 through the Historical Frame class. Indeed, the historical
 51 frame in which the recurrent event is situated includes the
 52 belief that St. Servatius drank from that cup. It is modeled
 53 as a belief, related to the believed thing through the newly
 54 added :believedThing relation (See module 8.2). A further
 55 relation :motivates marks the strong influence that the
 56 belief had on the practice, relating the Belief to the Object
 57 in the recurrent irregular event situation. As the believed
 58 event is not considered to be a fact that took place, it is
 59 modeled as a Propositional Object (crm:E89). Nevertheless,
 60 this choice hinders the possibility of expressing the change
 61 of function

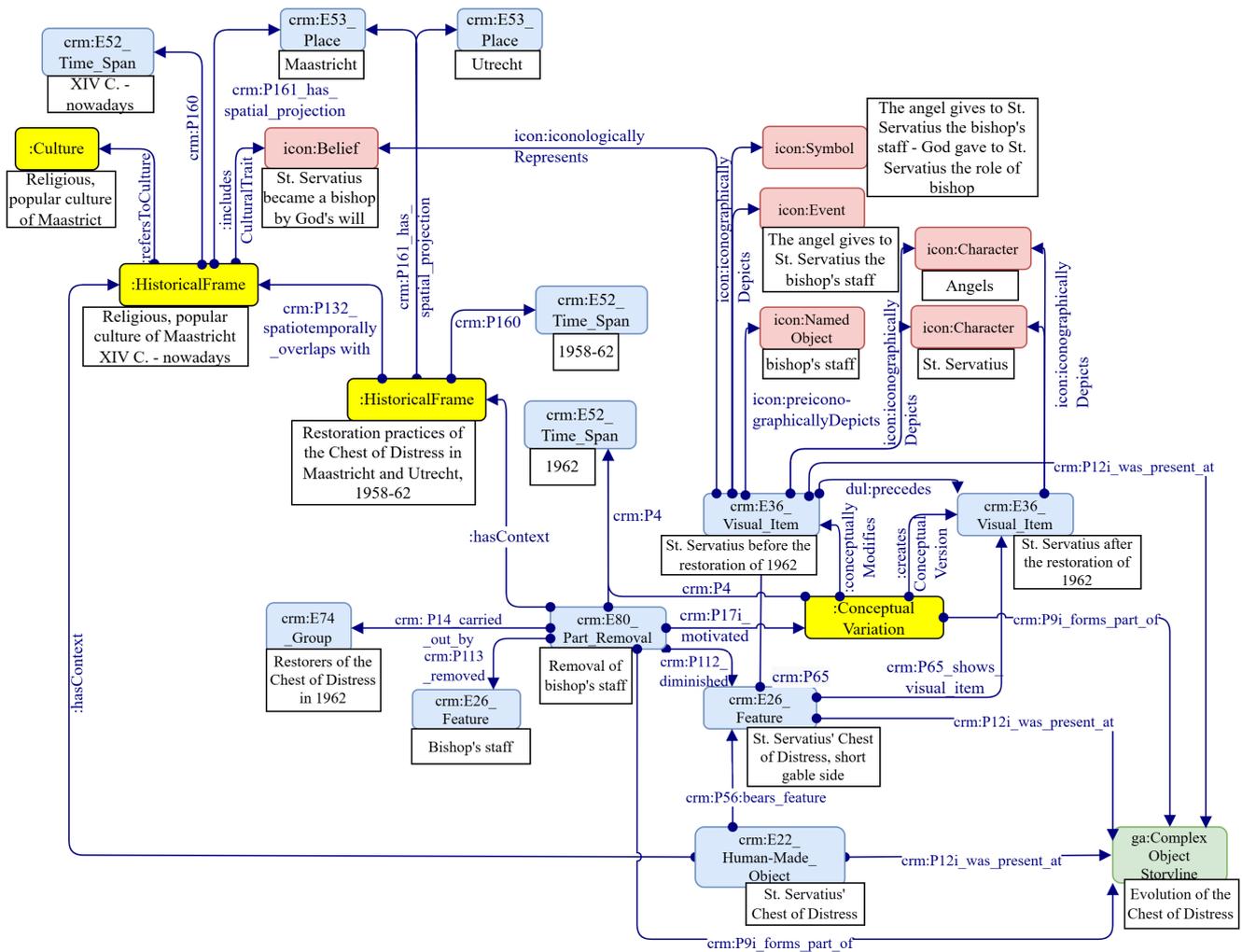


Figure 20. Modeling of the change of iconographical meaning of the scene representing St. Servatius as a bishop as a consequence of the restoration performed in 1962 (case 4)

1 the contextualization of the CH object in the immaterial
 2 context(s) that it traverses. Limitations of current modeling
 3 are a more detailed representation of 1) hypothetical or
 4 believed facts that are part of the culture (see Section 9.5)
 5 and of 2) the group of people for which specific cultural
 6 traits are true.

7 The introduction of a historical frame into the discourse
 8 as a spacetime unity is a novelty presented in this paper.
 9 It is considered to be fundamental in the CH hermeneutic
 10 discourse, as divergent cultural expressions and artistic
 11 solutions may be provided at the same time but in different
 12 places. Little research has been done on the spacetime
 13 unity in the discourse concerning endurants and perdurants
 14 in ontologies. Up to now in many models space and
 15 time have been treated separately, resulting potentially in
 16 inconsistencies in ontologies (e.g., the temporal classes of
 17 CIDOC-CRM E4 Period and E5 Event are subclass of
 18 E92 Spacetime Volume) or in their alignment. For this
 19 reason, further research will be done to provide alignments
 20 with the Storylines model. This research entails a further
 21 analysis of how definitions of views over storylines overlap
 22 with the provided concept of Historical Frame (Section 5.3).
 23 Storyline views are defined as perdurants which raises issues
 24 in the alignment with the Spacetime concept provided by
 25 CIDOC-CRM. This is defined as a four-dimensional entity

and is not related to CRM: E2_Temporal_Entity, the
 class in the CRM ontology defined as perdurant.

Evolution of the material and immaterial part of the object.
 The evolution of the physical object was represented through
 the reuse of CIDOC-CRM classes that indicate the processes
 of adding and removing parts and the transformation of
 an object. These classes were integrated in 8.3. In the
 same module, a new class was introduced to indicate the
 conceptual variation that changes the visual representations
 of a CH object, providing multiple versions of it. Being
 defined as perdurants, the events modifying the conceptual
 and physical aspects of the object can be declared as part
 of a ga:Storyline, described as a complex bundle of all the
 events in which the object participates, tracing in this way
 its evolution over time.

Evolution of the object function. A new module 8.1 was
 introduced to represent the specific functions, practical
 or social, that objects have in certain situations based
 on the AAAo ontology. The class Function Status
 allowing us to illustrate in detail the change of function
 over time. Being a temporal class, it may be included in a
 ga:Storyline, which is defined as a collection of events
 describing the evolution of a single endurant. Nevertheless,
 this solution requires further study on the alignment between

CIDOC-CRM and UFO, on which the Storyline model is based. We consider a new model of storylines that includes 1) spacetime unity and 2) socio-cultural characteristics.

Traits of recurrent and unique events. Custom solutions to include functions and events that recur regularly or irregularly, with extended patterns over time, have already been proposed for the description of regular events or situations (42; 41). The adopted solution allows the identification of a unique identity of a collection of events, independently of the definition of the frequency with which they are repeated over time. Each participating event can be described according to its peculiar characteristics. In this way, immaterial ephemeral practices, such as processions, can be described according to their persisting characteristics. Moreover, single events can be enriched with traits that are characteristic for them separately but not for the whole collection (e.g., a theme of the procession in a specific year).

Ephemeral events and objects. The contribution provided a first exploration of the nuances of the concept of ephemeral and how it can be represented with the currently available ontologies 8.4. Ephemeral events, intended as events of short duration, loosely characterized by fuzzy or uncertain time limits, can be described with CIDOC-CRM classes. These classes already address uncertainty and fuzziness in both E5 Events and the time spans that characterize them. Indeed, the E5 class includes performances and events which do not necessarily leave permanent traces, such as many ephemeral events. Actions and events belonging to intangible CH (such as the procession of St. Servatius) that meet the definition of ephemerality can be described as events including smaller activities. If not directly related, such ephemeral activities can still be grouped in the same `:HistoricalFrame` (see, for example, Figure 18, in which the activity of saying prayers is not directly included in the representation of the event of the procession, but narrowly relates to it). Further ontologies, such as the Odeuropa model, are useful to describe such ephemeral activities as the olfactory experiences involved in the Intangible CH practices. Nevertheless, more cases should be explored to identify further characteristics of intangible CH besides the ones that the St. Servatius' case presents. Generic time relations, such as `dul:precedes`, can be used to indicate order among ephemeral activities.

Fuzzy and uncertain limits over time can be further emphasized with the EDTF Specification for times. Nevertheless, the EDTF Ontology provides a mapping between such a specification and the Time Ontology. It follows the XSD format, standard for RDF, but is still a draft. Furthermore, the subtle differences in representations of time between CIDOC-CRM, DOLCE, and the Time Ontology make it difficult to provide a fully compliant solution to express uncertainty not only in the classes representing time but also in the computable time intervals delimiting them.

Another nuance of ephemeral grasped in the model is the definition of ephemeral as a type of CH objects, which are created for a unique occasion and not made to last over time. In this case, the ephemerality of objects (and related events) can be grasped through controlled vocabulary terms. Such modeling constitutes a first solution towards a

more consistent ontological representation of CH ephemeral objects.

10.3 Future Work

The CIDOC-CRM and DOLCE ontologies were extended in four modules and combined with classes of AAAo, ICON, the Time Ontology, Storylines, and the EDTF Ontology, to represent relevant aspects of the interactions between tangible and intangible CH. Common alignments have not yet been incorporated to avoid potential inconsistencies between the ontologies used. Alternatively, classes aligned with different ontologies are related in the model through properties. The proposed ontological framework can be further integrated with recently released ontologies that address the representation of social facts, such as the Semantic Data for Humanities and Social Sciences SDHSS-extension of CIDOC, which is also based on DOLCE. This may integrate our model with more detailed information on the societal traits considered to be relevant in the framed context(s).

Interactions between objects of tangible and intangible CH were presented as storylines that often could be well defined in spacetime, but in other cases, such as in ephemeral events, were fuzzy. This implies that in the storylines elements of uncertainty are introduced. With the aim in mind to use historical frames to analyze and present evidence-based histories further research is foreseen. This research is intended to establish how the historical frame system can be connected to ontological models of uncertainty. These models must be able to deal with various types of uncertainty, such as in vagueness ontologies (57; 58), but also with the different phases in which uncertainty can occur.

Although the problem of uncertainty in the temporal modeling of interactions between tangible and intangible CH cannot be solved immediately, further research and modeling is foreseen in the short term²⁶. Future work includes furthermore additional alignments with existing ontologies and extensions of tangible and intangible CH interactions models based on more interdisciplinary case studies (e.g., material culture, anthropology, social sciences).

Notes

- Mexico City Declaration on Cultural Policies, introduction statement, p. 1: "culture may now be said to be the whole complex of distinctive spiritual, material, intellectual and emotional features that characterize a society or social group. It includes not only the arts and letters, but also modes of life, the fundamental rights of the human being, value systems, traditions and beliefs."
- In this paper, we refer to version 7.1.3, the last official version of the ontology (56).
- <https://marilenadaquino.github.io/hico/>
- for a comprehensive overview, see (59)
- <https://s3.amazonaws.com/VRA/ontology.html>
- <https://ontology.swissartresearch.net/aaao/>
- Scope note of the class `crm:E81_Transformation` in version 7.1.3 (current official version): "Even though such instances of E81 Transformation are often motivated by a

- change of intended use, substantial material changes should justify the documentation of the result as a new instance of E18 Physical Thing and not just the change of function. The latter may be documented as an extended activity (instance of E7 Activity) of using it” (56)
8. <https://cidoc-crm.org/crmsci> and version for approval <https://cidoc-crm.org/sites/default/files/CRMsci-v.2.2%20%28draft%29.pdf>. This version is compatible with CIDOC-CRM Version 7.2.1.
 9. In this paper, the reference is made to the DOLCE+D&S Ultralite release.
 10. CIDOC-CRM Version 7.1.3 March 2024 defines the scope of the class E4 Period sets of coherent phenomena or cultural manifestations occurring in time and space. Being a subclass of E92 Spacetime Volume it is incoherent that space makes part of this E4 definition, and a reconsideration of the scope note is suggested for making their relations more consistent.
 11. As the `crm:E92` class is the only one including a unity of spacetime volume in a CH domain ontology, we here refer to it. This for the reason that the discourse of inclusion of a timespace unity in standards and foundational ontologies (BFO ontology and DOLCE+D&S Ultralite) is out of the scope of this paper.
 12. `aat:300387639` “ephemeral art”; `aat:300007997` “temporary structures”; `aat:300165202` “temporary buildings”. See the full description at <https://www.getty.edu/research/tools/vocabularies/aat>
 13. <https://www.loc.gov/standards/datetime/>
 14. <https://github.com/periodo/edtf-ontology>
 15. <https://www.w3.org/TR/owl-time/>
 16. see note 1
 17. Historical Center Limburg Maastricht 21.412 – inv. nr 1: Jérôme Goffin [...] 1 Sketches and designs made for the Septennial Pilgrimage in Maastricht 1958-1962.
 18. Historical Centre Limburg in Maastricht Sint Servaas I 21.209A - 139 Registrum Pastorale 1840-1969 between folio 26-27 a paper article mentioning the order of objects in the “grande procession de St. Servais” of 1881 object 27 “La coupe de St. Servais and 29 Des corps des SS. Servais et Martin dans la grande chasse, dite Noodkist. Further, II 21.209B -56, Archief Kapittel St. Servaas no. 166 Ordinarius Custodum 38v.
 19. Specifically, the modules extend the DOLCE+DnS Ultralite ontology version 4.2 and the CIDOC-CRM model, version 7.1.3. <https://github.com/SofiBar/CulturalHeritageHistoricalContext>
 20. In this one and all the following tables of the sections, the quoted descriptions are taken from the documentation of the respective ontology
 21. **Although this work focuses on the reuse of ICON classes only, other ontologies representing traits of a societal context, such as their values, ideas, social facts, (e.g., ValueNet, AAAo, SDHSS), can be connected to a Historical Frame through the property `:includesCulturalTrait`**
 22. The definition of the class `:HistoricalFrame` partially reflects the one given for the E4 Period class, in which a period is recognized as having its own identity (e.g., Renaissance). However, in case a specific object needs to be examined in more detail, the focus can be on the identities of specific groups or subcultures that co-exist in the same period, but that may not be commonly recognized as having their own identity (40). Despite the similarity in the definition, the `:HistoricalFrame` is not defined as a subclass of E4 to avoid the inheritance of possible inconsistencies on the nature of perdurants (see Section 4.3).
 23. In 16th Century Germany, there are examples of a peaceful coexistence of different branches of Catholicism and Protestantism using the same religious spaces and liturgical objects. See the “Shared Churches” project at: <https://sharedchurches.arizona.edu/>
 24. **In CIDOC-CRM, the class `E81Transformation` indicates that the physical modification had an impact on the identity of the object, transforming it into a new one. Although it allows to indicate different instances of material objects, which would correspond to different versions of it, it clearly states that the identity of the object changes. For this reason, it is not suitable for cases in which no substantial transformation occurs during restoration activities.**
 25. These properties are chosen as they express the relation between endurants and perdurants in an equivalent way to the Storyline model, based on UFO
 26. A proposal by the authors for the publication of the paper “Opening Boxes: Contextualizing a 3D Scholarly Edition of the Restoration of the 12th Century Reliquary Shrine of St. Servatius with Ontologies of Uncertainty” presented at the conference *Digital Art History-Methods, Practices, Epistemologies V: Critical Approaches to Sources in (Digital) Art History, Zagreb 16 Oct 2025* in a special issue of *Život umjetnosti Journal for Modern and Contemporary Art and Architecture* has been accepted.

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