ECHOES
European Cloud for Heritage Open Science

Heritage Digital Twins Ontology

Version 1.1

Work Package WP7
Digital Commons Knowledge-Base

HORIZON-CL2-2023-HERITAGE-ECCCH-01

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List of Abbreviations

CRM CIDOC Conceptual Reference Model

CRMsci Scientific Observation Model

CRMdig

CRMinf

RDF/S Resource Description Framework Schema

1 Executive Summary

This report consists of the second draft of the Heritage Digital Twin ontology (HDTO), published in February 2026, developed as the base data model for enabling the ECHOES' "digital commons", addressed here as "Heritage Digital Twins" and defined as: "The state-of-the-art of digital information about a real-world heritage asset, with its tangible and intangible components, describing its properties and capturing its space-time-culture identity, formally organised in a semantic framework and described by the CRM - based ontology (HDTO)". It is the evolution of the first draft of the HDTO:

https://www.echoes-eccch.eu/wp-content/uploads/2025/06/ECHOES_HDT_Ontology.pdf

The final version of the Heritage Digital Twin Ontology will be published by June 2026.

2 Introduction

Purpose and Scope of the Document

The purpose of the document is to present the Heritage Digital Twin ontology (HDTO), its scope being to provide the theoretical framework necessary for the development of the implementation framework on the management of digital commons in ECHOES and ensure their digital continuum.

Structure of the Document

The document presents the theoretical considerations and the description of the HDTO, followed with a practical example on how the data model described with the HDTO is used to represent work done at The Cyprus Institute, in collaboration with other institutions representing various communities, on the analysis of the Deryneia icon (presented at the end of the document).

3 Heritage Digital Twin Ontology

Status of this work

This work is a draft that reflects the ongoing effort on the ECHOES data model. As of today, it is not intended as a fully-fledged data model. Rather, it presents a selection of core elements that we foresee to be the base of the coming ontology. As the first official release is scheduled on 05-2026, we expect that the contents of this document could change, possibly drastically, until then. In the next steps we will refine the selection of elements and illustrate how they can be used to represent knowledge about real-life data.

Approach to the data model

Our current effort is aimed at developing the Heritage Digital Twin Ontology (HDTO). It is defined as an extension of the standard ISO 21127:2023 reference model CIDOC CRM. Our effort can be seen as one of selecting elements from the CIDOC CRM and its extensions, in order to capture fundamental aspects of Heritage Digital Twins (HDT).

The current selection of classes and properties is proposed as a review, an improvement and clarification of an earlier data model presented in https://arxiv.org/pdf/2302.07138.

The description includes comments and proposes changes on the basic entities and relationships. It includes refinement on the scope notes, reviews on the existing properties (changes in the domain or range), addition of new properties and addition of sub-class and sub-properties relationships.

The proposed modifications are necessary in order to remain compliant with the respective ontologies that the model extends and harmonise (CIDOC CRM version 7.3, CRMsci version 3.0, CRMdig version 4.0, CRMinf version 1.2, Parthenos model[1] v3.1, etc.), reduce complexity, make possible effective integration and increase extensibility. Additionally, it takes into account the proposed revision of the current version of CRMinf and CRMsci, which includes a simplification of the documentation of premises and conclusions, an extension to a multi proposition observation (unifying reification and named graphs) and measurements of dimensions relating multiple entities

In practice, the proposed changes include:

- providing a general pattern how to relate references to reification patterns to sets of propositions.

- include better modelling practices, such as the identification of classes to describe a common generalisation of existing ones, and the creation of sub properties, which help to make the model robust and efficient and maximise the integration procedure.

Naming Conventions

The HDT ontology is an extension of CIDOC CRM and follows the naming conventions that have been applied throughout the CIDOC CRM. All the new declared classes and properties were given both a name and an identifier constructed according to the conventions used in the CRM base model. For classes, that identifier consists of the letters HC (Heritage Class) followed by a number. Properties were also given a name and an identifier, constructed according to the same conventions. That identifier consists of the letters HP (Heritage Property), followed by a number, which in turn is followed by the letter "i" every time the property is mentioned "backwards", i.e., from target to domain (inverse link). "HC" and "HP" do not have any other meaning. They correspond respectively to letters "E" and "P" in the CRMbase naming conventions, where "E" originally meant "entity" (although the CRMbase "entities" are now consistently called "classes"), and "P" means "property". Whenever CRMbase classes are used in our model, they are named by the name they have in the original CRMbase. The same applies for all the extensions which also follow the same conventions.

Currently the HDT ontology includes references to the following external models:

- [CIDOC-CRM v7.1.3](#)
- [CRMdig v5.0](#)
- [CRMsci v3.0](#)
- [CRMinf v1.2](#)
- [Parthenos model v3.1](#)
- [LRMoo v1.0](#)
- [Narrative Ontology v2.0](#)

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[1]https://cidoc-crm.org/sites/default/files/D5.5_Common_semantic_Framework_with_Appendices.pdf

Notes on Basic Concepts of the Ontology

The most general notion of the model, its focal concept, is **HC1 Heritage Entity**, which denotes anything of the real world regarded as valuable because of the contribution to society, knowledge and culture. In that sense, what distinguishes this general concept from the others is the value that acquires (a functional characteristic) some entity relative to the society and culture. This characteristic is a dynamic, contextual attribute that is produced by the society. As such, it constitutes a role, i.e., in the sense of the DOLCE ontology[2], it does not carry a condition for identifying an instance to be distinct from others and to be diachronically the same or not. This means that the item characterized as Heritage Entity exists independently; its nature and identity does not change or depend on the heritage (social) context.

Open question: The term heritage has meaning on multiple levels of human perception, intention and interaction served by multidisciplinary approaches and methodologies that can be developed and used worldwide. Does it include natural heritage? Cultural heritage is in the scope of inquiry of a range of humanities, social sciences and environmental studies. It needs further specification.

The classification of an entity as HC1 reflects an intention or reality of the management or socially rooted treatment of the entity by the declaring authority according to an agreement and a valuation of its role in the primary contextual society that justifies the classification. As such, the identity of the concept is a projection of a relationship to one of the related entities which does not pertain to its substance or individual identity. Rather, identity conditions will be those of the respective ontological categories it belongs to.

The concept "heritage entity" is defined by an authority that acts on behalf or in favour of the contextual society within a specific contextual period (e.g. UNESCO European policies or a decision by a Europeana partner to digitise and submit an item for aggregation into Europeana). A project documenting entity in a knowledge base as instances of HC1, as a relevant additional characterization beyond the general provenance and use of Human-Made or other Things, may decide to include things or traditions regarded as particular heritage by informal or traditional communities as well.

If such a distinct social context cannot be established, there is no reason to classify an item as instance of HC1 in a knowledge base, because ontological classes neutral to such context (for example classes for "book" or "building") will allow for documenting all what should be, regardless whether national or other authorities summarily regard some categories of items as heritage. *Not*

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[2] https://www.loa.istc.cnr.it/dolce/overview.html

documenting an item as instance of HC1 in a knowledge base does *not* constitute a statement about not being heritage in some sense.

«*The main class is Heritage Entity, comprising tangible and intangible entities of the real-world regarded as valuable because of their contribution to society, knowledge and/or culture. The tangible and intangible heritage entities of the same Heritage Entity are recorded as Tangible Heritage Entity and Intangible Heritage Entity. While all Heritage Entities are related to an intangible heritage entity, some Heritage Entities may not have the tangible one and only exist as intangible.* »

Open question: The latter do not include Actors as instances, therefore HC1 should probably be subclass of E70 Thing and not directly of E77 Persistent Item. It may however be argued that a particular organisation existing over multiple generations could also be regarded as an HC1. In that case, Tangible Heritage Entities would differ from the entity associated with the Digital Twin.

HC1 serves as an entry point for linking to HC2.

HC2 Heritage Digital Twin concept constitutes an epistemic consideration which may vary in point of view and scale between different authors. Updating an instance of HC2 does not make the previous disappear, as with all Conceptual Objects. Therefore, an instance of HC2 should be identified by its propositional content and creating Actor.

If uniqueness is required, it constitutes an attribute assigned to one instance by and relative to a particular Actor, typically even a project. In that sense, there are no other objective criteria to distinguish a digital twin from another. Therefore, contents of different instances may include or overlap each other.

Therefore, rather its contents and not the instance itself constitutes robust concepts that can be shared in a discourse and are unambiguous across contexts.

In other words, the notion of a Heritage Digital Twin instantiated by a node in a semantic network makes only sense with respect to a particular functional role in a project context, representing facts that an information provider has agreed to provide digital material about.

Consequently, the structural relationship connecting HC2s ("HP3 is digital twin component of (has digital twin component")) is created following a decision taken by the content providers as well as the relation that connects HC2 to HC1, connecting in practice to HC3 or HC4.

Subgranular Spatio-temporal Elements

HDT components can optionally connect to subgranular spatio-temporal elements that provide detailed documentation of discrete portions of the heritage entity. These elements are defined by their spatial and temporal boundaries rather than by material composition, enabling systematic documentation of heritage evolution and complex interventions.

For tangible heritage entities, subgranular elements represent discrete spatio-temporal portions such as construction phases, architectural components, or intervention areas. For intangible heritage entities, subgranular elements represent discrete performance instances, ritual phases, or tradition variants that occurred within specific spatial and temporal boundaries.

The connection to subgranular elements enables HDT to maintain its heritage-focused perspective while providing pathways to specialized documentation domains through formalized linking mechanisms.

4 HDTO Class Declaration

In the temporary page https://isl.ics.forth.gr/ontology/echoes/html/HDT_v1.1.html you can navigate through Classes & Properties declarations of version 1.1 by:

- o Scrolling up/down the current page.
- o Using the hyperlinks defined for each Class or Property identifier (e.g. HC1 Heritage Entity).
- o Using the control located at the upper-right corner of this page (Click on 'Navigate to a section' text). Type any part of the Class or Property full name, and press Enter or select the preferred option in order to be automatically navigated to the relevant declaration.

HC1 Heritage Entity

Subclass of: crm: E70 Thing

Superclass of: HC3 Tangible Heritage Entity
                          HC4 Intangible Heritage Entity

Scope Note:

> This class comprises tangible and intangible entities of the real-world declared as valuable because of their contribution to society, knowledge and/or culture. The value that a heritage entity acquires is relative to the society and culture that assigns it each time. Instances of HC1 Heritage Entity may constitute real assets of any nature: physical, both movable and immovable, immaterial, or born digital. They may also constitute types or patterns of cultural events, traditions and practices, typical of the intangible heritage that should be documented with their features and their extent in space and time. Individual events are not considered instances of HC1 Heritage Entity. Rather, they can be related via their types or patterns to an

instance of HC1 Heritage Entity. An instance of HC1 can be considered as the focal item for aggregating the content of its corresponding HC2 Digital Twin instance.

Parts of an instance of HC1 Heritage Entity may or may not constitute Heritage Entities in their own right, such as a shop in a historical building.

Examples:

the Knossos Palace (HC1), part of the Knossos WH archaeological site (HC1)

the Pafos Gate in Nicosia

the "Palio di Siena"

the Florence Historical Centre, a WH Site

the Stonehenge Complex, a WH site

 the Bauhaus style

The Dresden Elbe Valley

Properties:

HP1 has digital twin (is digital twin of): HC2 Heritage Digital Twin

HP2 has story (is story about): nont:narrative

HP15 is heritage of (has original heritage): crm:E74 Group

HC2 Heritage Digital Twin

Subclass of: HC14 Volatile Digital Object

Superclass of:

Scope Note:

The class comprises collections of sets of formal propositions related to an instance of HC1 Heritage Entity that are documented as single units and serve as topic of discourse about the latter.

Characteristically, the collected sets of propositions may relate information available in a given system including digital visual representations (e.g. 3D models, images, videos), textual descriptions (e.g. digital documents, narrations or stories), information of the effects or images of events that influenced or/and are related in any way to the state of the respective Heritage Entity (e.g. earthquakes, floods etc.) and of activities (e.g. restorations, conservations etc.) carried out on it.
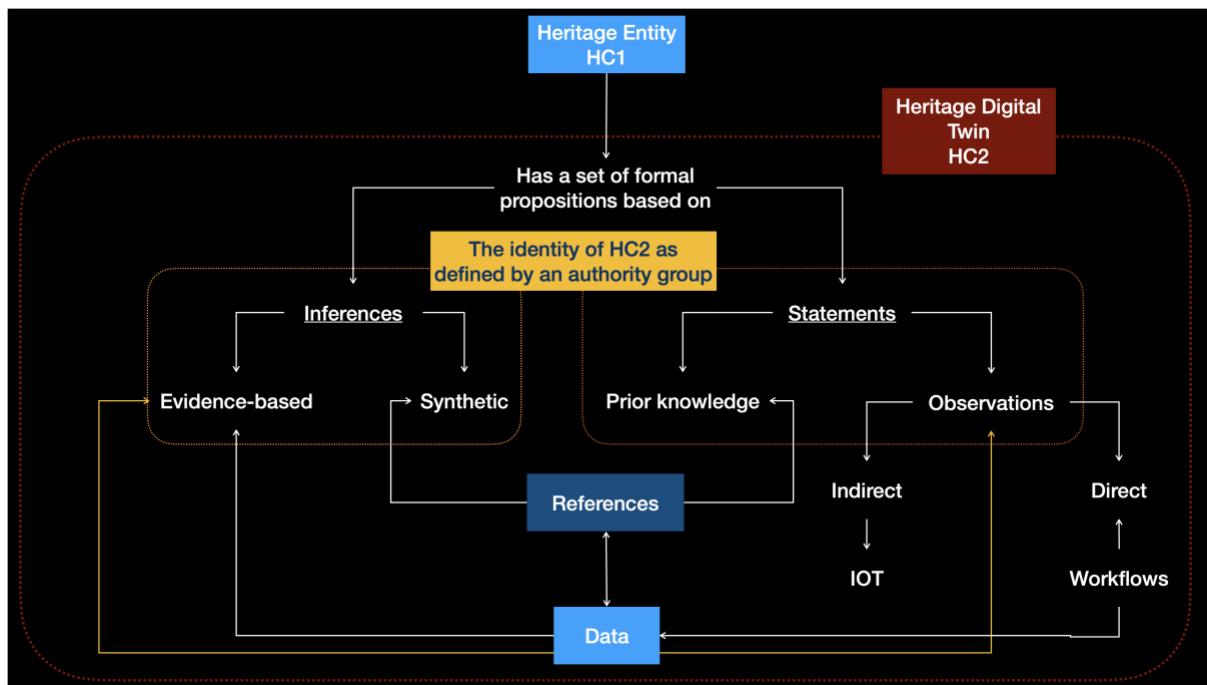
In the context of a defining project or authority, every instance of HC2 Heritage Digital Twin should be linked to one instance of HC1 Heritage Entity and is valid for a specific time-span. It aims at providing an archive of the documented history, traits and social relationships of the corresponding HC1 Heritage Entity. However, there may be multiple instances of HC2, created by different projects, that may overlap or include each other as they are related to the same HC1. The creation of an instance of HC2 depends on the valuation of a heritage entity, since the classification of an item as heritage entity itself primarily depends on the valuation.

An instance HC2 Heritage Digital Twin [3] is composed of one or several (persistent) instances of HC16 Heritage Proposition Set, which may be added to, deleted from or replaced in the Digital Twin at any point in time via distinct actions that are each one an instance of HC11 Digital Twin Maintenance. HC2 is therefore a subclass of HC14 Volatile Digital Object (in the sense of the **Parthenos Entity Model[4]** Care should be taken that all information referred to in the ⬚content ⬚units having constituted a Digital Twin at any point in time can be traced back to persistent ("fixed"), **citable** or at least permanently accessible documents, which the respective studies should anyhow independently have provided according to scientific practice.

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[3] **PE24 Volatile Dataset** comprises datasets that are changed without notice or archiving of intermediate states but maintained by an instance of PE12 Data Curating Service. The identity of a volatile dataset is enabled by the unity given to it by curation programme that operates on it, that bequeaths the volatile dataset common information goal and subject coverage. In order for an instance of PE24 Volatile Dataset to be referenceable it is necessary for the official curator to take snapshots, creating instances of PE22 Persistent Data Set which can be assigned and official identifier and referenced. Volatile datasets are typically whole databases or mash-ups with active data feeds.

[4] **PE24 Volatile Dataset** comprises datasets that are changed without notice or archiving of intermediate states but maintained by an instance of PE12 Data Curating Service. The identity of a volatile dataset is enabled by the unity given to it by curation programme that operates on it, that bequeaths the volatile dataset common information goal and subject coverage. In order for an instance of PE24 Volatile Dataset to be referenceable it is necessary for the official curator to take snapshots, creating instances of PE22 Persistent Data Set which can be assigned and official identifier and referenced. Volatile datasets are typically whole databases or mash-ups with active data feeds.

Examples:

the HDT of Pisa Leaning Tower

the HDT of the Neptune Fountain in Bologna

the HDT of Knossos Palace

the HDT of the Pafos Gate in Nicosia

the HDT of the "Palio di Siena"

the HDT of the Florence Historical Centre

Properties:

HP3 is digital twin component of (has digital twin component): HC2 Heritage Digital Twin

HP33 contains (is proposition set of): HC16 Heritage Proposition Set

HP34 contained (is former proposition set of): HC16 Heritage Proposition Set

HC3 Tangible Heritage Entity

Subclass of: HC1 Heritage Entity

crm:E18 Physical Thing

Superclass of:

Scope Note:

This class comprises tangible, material entities of the real-world, both movable (e.g. archaeological, artistic and cultural objects) and immovable (e.g., built heritage like monuments, buildings, cities and other complexes), regarded as valuable because of their contribution to society, knowledge and/or culture. The "tangible" term in the name of this class does not exclude that its instances also possess an intangible heritage entity, which is specified through the HP5 has intangible heritage entity property.

The digitization of an HC3 is represented by crmdig:L1i was digitized by crmdig:D2 Digitization Process inherited by CRMdig.

Examples:

the Neptune Fountain in Bologna (Italy)

the Pisa Leaning Tower

the Nike of Samothrace of the Louvre Museum in Paris (France)

Properties:

HP5 has intangible heritage entity (is intangible heritage entity of): HC4 Intangible Heritage Entity

HP7 is manifestation of (is manifested by): HC4 Intangible Heritage Entity

HC4 Intangible Heritage Entity

Subclass of: HC1 Heritage Entity

crm: E89 Propositional Object

Superclass of:

Scope Note:

This class comprises expressions and declarations of cultural events, traditions and practices having particular social, historical and cultural significance, including practices and expressions, memories and oral traditions about events, things, people. An Intangible Heritage Entity is identified by a society or by evidence or other kind of manifestations. The identity of an Intangible Heritage Entity results from an agreement and a validation made by a group of people for a specific time-span.

Examples:

the Mediterranean diet
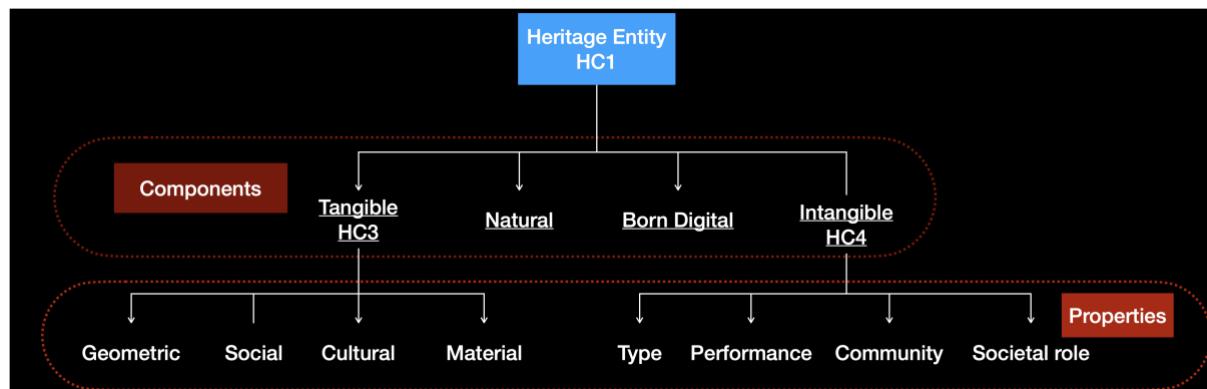
Falconry

the Rebetiko music tradition

the "Palio di Siena"

Properties:

HP6 has manifestation event (event is manifestation of): crm:E5 Event

HC5 Digital Representation

Subclass of: crmdig:D9 Data Object

Superclass of:

HC7 Digital Audiovisual Object

HC8 3D Model

Scope Note:

This class comprises the digital virtual representations of an crmsci:S15 Observable Entity, in particular representing the HC3 Tangible Aspect of an HC1 Heritage Entity or tangible parts of the latter, such as images of objects, sites, scenes or paper documents, audio or video items, 3D models, that are documented as single units. Instances of HC5 Digital Representation constitute documents in the sense of crm:E31 Document and inherit its properties.

For documenting pieces or collections of digital, non-visual documents, either born-digital or physical, real-world ones, typically containing textual or information regarding an HC1 Heritage Entity and intended to be referred to or to become part of the related HC2 Heritage Digital Twin, use the more general class of crm:E31 Document.

For scientific data and audio-visual document, including video and digital 3D models, use the more specific classes of this model, meaning HC7 Digital Audiovisual Object and HC8 3D Model.

Examples:

The digital version of Vasari's "Vite"

the video https://www.youtube.com/watch?v=P1Uv4Zf5xKk

the Pafos Gate laser scanning 3D model

Properties:

HP22 represents (has digital representation): crmsci:S15 Observable Entity

HC7 Digital Audiovisual Object

Subclass of: HC5 Digital Representation

Superclass of:

Scope Note:

This class comprises digital visual objects, such as photos and videos, but also special imagery such as X-ray images, spectra of chemical and physical analyses, and so on, intended to

become part of the HC2 Heritage Digital Twin of an HC1 Heritage Entity. Digital documentation of this kind can be born digital or digitised from physical objects (such as paper photographs, drawings and so on). Particularly relevant digital visual objects are also Virtual Reality (VR) and Augmented Reality (AR) models, other types of visual digital artefacts pertaining to a HC1 Heritage Entity. Both VR and AR models rely on 3D models of the related heritage entity, but may add or remove parts of it, or require further digital input as in AR, so they should be catalogued separately from 3D models.

Examples:

The Europeana digital version of the paper picture of the Pisa Leaning Tower taken by Paolo Monti in 1960

(https://www.europeana.eu/it/item/9200369/webclient_DeliveryManager_pid_6363979_custom_att_2_simple_viewer).

Properties:

HP9 is visual representation of (has visual representation): crmsci: S15 Observable Entity

HC8 3D Model

Subclass of: HC5 Digital Representation

Superclass of:

Scope Note:

This class is used for rendering in detail the 3D model of HC1 Heritage Entity and intended as a particular crmdig:D1 Digital Object having its definite identity and resulting from operations such as digitization, acquisition, processing and other actions typical of the three dimensional modelling world (e.g., 3D scanning, wireframe modelling and so on). The particular features of a 3D model (e.g., its type, format, resolution, size, etc.) and its relationships with the series of activities carried out for its creation and manipulation are modelled through the properties inherited from its superclass HC5, which in turn inherits from crmdig:D1 Digital Object, and through the other classes and properties of CRMdig.

Specifically, information regarding the creation of a 3d model as a result output of a digitisation process can be documented using the property path from crmdig crmdig:D2 Digitization Process *crmdig:L20 has created* HC8 3D Model and respectively information

regarding the digitisation of the material object is represented by crm:E18 Physical Thing *crmdig:L1i was digitized by* crmdig:D2 Digitization Process.

Examples:

The 3D model of the Neptune Fountain produced by ISTI-CNR (Pisa, Italy) as part of the documentation used for the restoration of the Neptune Fountain in Bologna (Italy). https://www.cnr.it/en/focus/074-43/3d-supported-restoration-the-neptune-fountain-inbologna.

Properties:

HP21 is 3D representation output of (has 3D representation): HC1 Heritage Entity

HC9 Study

Subclass of: crm: E65 Creation

Superclass of:

Scope Note:

This class comprises activities of analysing heritage entities or other material and immaterial items or events related to heritage entities and studying their relevant contexts throughout the past, with the purpose of revealing and documenting their nature and significance for past, current and future societies, as well as preserving themselves and the knowledge about them for future generations. The results of an instance of HC9 Study may be in the form of a scientific or scholarly publication or a dataset.

Characteristically, instances of HC9 study occur in units given by different disciplinary aspects or skills, such as history of art, conservation history, carbon 14 dating and many others. Ideally, the study of the different disciplinary aspects should inform and provide arguments for each other. For instance, techniques or materials identified by conservation science may allow for narrowing down time and area of production in for a history of art study. On the other side, historical knowledge may help excluding certain materials during the interpretation of chemical analysis.

Instances of HC9 Study may directly be related to the execution of a particular scholarly workflow aiming at systematically planning, finding or initiating studies and collecting their results until they cover all disciplinary aspects intended by a respective project. The progress

of such a workflow, constituting an intentional sequence of activities and a coherence of outcomes of the involved activities, can be documented by the inherited crm property *"P134 continued (was continued by)"* between instances of HC9 Study.

The results of an instance of HC9 Study should be documented in a persistent ("fixed"), citable or at least permanently accessible form according to scholarly and scientific practice, independently from being represented partially or completely within an instance of HC2 Digital Twin.

If an instance of HC9 Study occurs in the framework of an instance of **HC13 Project**, the relationship should be documented with the property *crm: P9 consists of (forms part of)*, such as "The creation of the 3D reconstitution of the Tour de Choeur of Notre-Dame de Chartres cathedral (HC9) *forms part of* The ChArtRes project (HC13)" or with the property crm *P17 was motivated by (motivated),* if the HC13 Project is regarded as a reason for carrying out the study.

The realization of a HC9 Study on an object should start a HC10 Heritage Valuation Event if no valuation from institutions or communities was previously documented. The interest from the community and the results of the study are proof of valuation of the object as an HC1 Heritage Entity, which might end up as a proper declaration (HC12 Heritage Declaration Event). Another HC9 Study might as well determine the declaration of the object as an HC1 Heritage Entity because of its results.

Examples:

- The Heritage Science research on the Portrait of Caterina Cornaro.
- The multi-dimensional analyse and the memorization made during the restoration of Notre-Dame cathedral.
- The filming of archeological excavations/activities on the Sobibor extermination camp remains
- The studying of the ornaments on the Tour de Choeur of Notre-Dame de Chartres cathedral
- The studying of the neurological effects of the sound of Aztec death whistles on the human brain
- The analysis and measurement made to produce the 3D reconstitution of the Tour de Choeur of Notre-Dame de Chartres cathedral
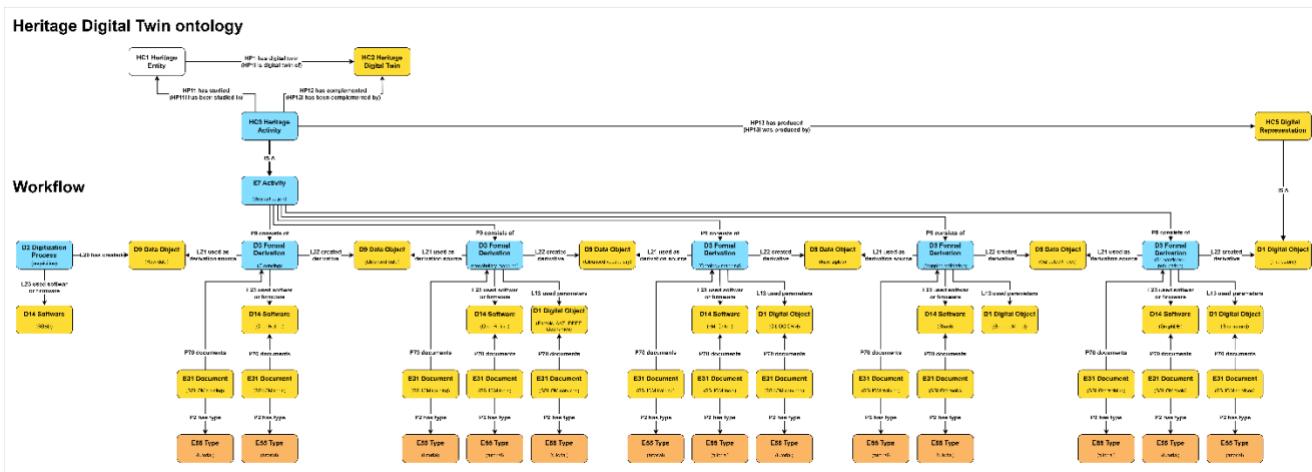
Properties:

HP23 was about (was subject of): HC1 Heritage Entity
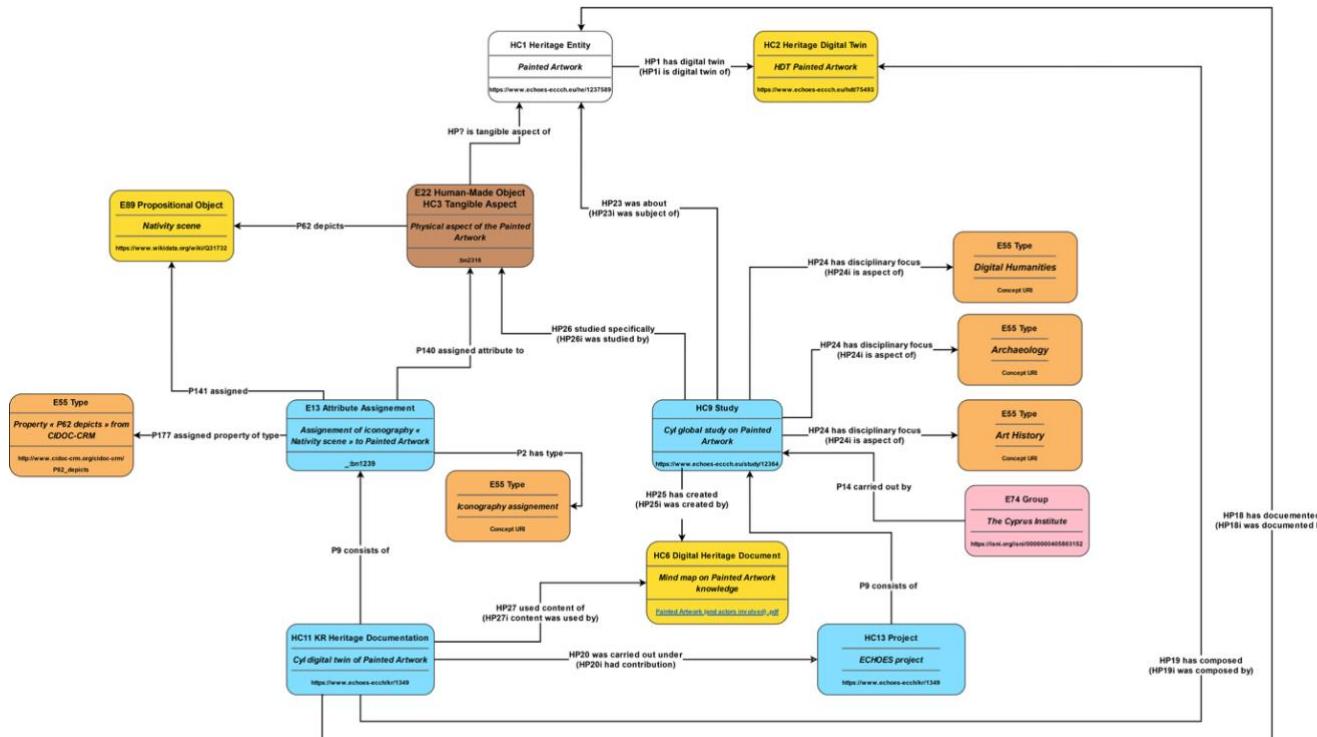
HP24 has disciplinary focus (is aspect of): crm: E55 Type
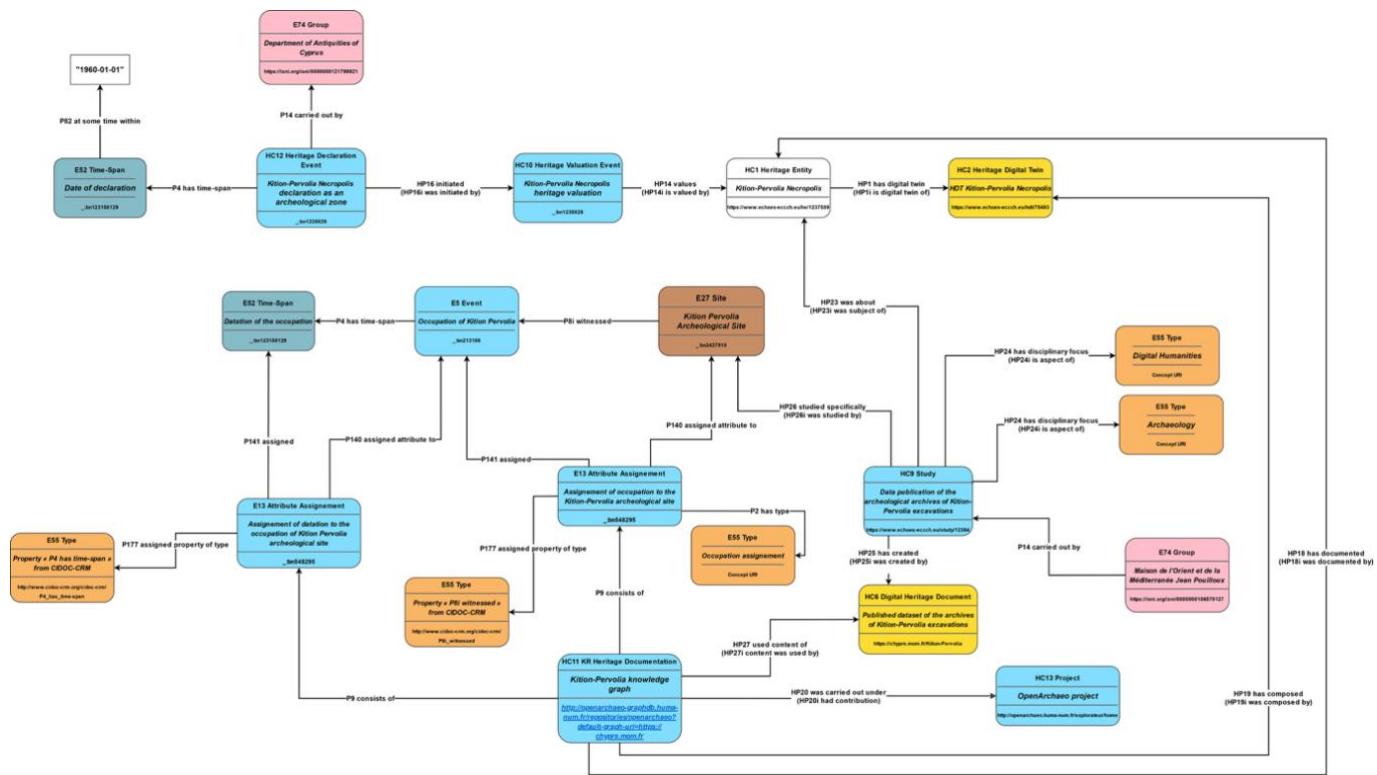
HP25 has created (was created by): crm: E31 Document

Heritage Digital Twin ontology

https://drive.google.com/file/d/1drnMkYEXrvo8sPW5Gbv4q-f8wM3AgH3C/view?usp=drive_link

HC10 Heritage Valuation

Subclass of: crm: E2 Temporal Entity

Superclass of:

Scope Note:

> The class comprises the continued characterizations of instances of E70 Thing as instances of HC1 Heritage Entity. An Instance of HC10 constitutes a so-called institutional fact, i.e., it comes into being by declaration by a competent authority and a related community respecting the declaration. It ends either with the loss of the heritage entity, the termination of its status by the declaring authority or the loss of respect of the declaration or declaring authority by the related communities.

> An instance of Heritage Valuation will characterize the Heritage Entity as being heritage in the narrower sense of a local community which created it and/or for which it constitutes its active tradition, object of tradition or believe system.

Examples:

> The valuation of the Dresden Elbe Valley in Germany in March 2004 by ICOMOS (ICOMOS, 2003)

Properties:

> HP12 regards as origin (is regarded as origin by): crm:E74 Group
>
> HP13 had target (was community for): crm:E74 Group
>
> HP14 values (is valued by): HC1 Heritage Entity

HC11 Digital Twin Maintenance

Subclass of: crm: E65 Creation

Superclass of:

Scope Note:

> The class comprises the documentation of information about a heritage entity in the form of knowledge representation ("KR") statements in order to create or to maintain an instance of HC2 Heritage Digital Twin that aims at representing or linking to the knowledge about this entity from relevant scientific and scholarly disciplines and its provenance. Such knowledge is typically the result of an instance of HC9 Study. The collection as a Digital Twin is carried out on behalf of a project which maintains a consistent and coherent knowledge base contributed by such studies.

> Since instances of HC2 Heritage Digital Twin are volatile objects in the sense of the **Parthenos Entity Model,** care should be taken that all information in the Digital Twin can be traced back to persistent ("fixed"), citable or at least permanently accessible documents, which the respective studies should anyhow independently have provided according to scientific practice.

> Instances of HC11 Digital Twin Maintenance should directly be related to the execution of a particular scholarly workflow aiming at systematically planning, finding or initiating studies and collecting their results until they cover all disciplinary aspects intended by a respective project.

Examples:

- The Deryneia icon Digital Twin Creation by CyI

Properties:

HP18 has documented: HC1 Heritage Entity

HP19 has composed (was composed by): HC2 Heritage Digital Twin

HP20 was carried out under (had contribution): HC13 Project

HP27 used content of (content was used by) : E31 Document

HP30 added content (content was added by): HC16 Heritage Proposition Set

HP31 deleted content (content was deleted by): HC16 Heritage Proposition Set

HC12 Heritage Declaration Event

Subclass of: crm:E13 Attribute Assignment

Superclass of:

Scope Note:

The class comprises statement activities that lead to the identification and declaration of instances of E70 Thing as instances of HC1 Heritage Entity heritage entity because of their accepted value and contribution to society, knowledge and/or culture. They are activities carried out by legal committees and authorities that decide, report and designate heritage entities following a guideline and specific criteria.

Examples:

- The UNESCO listing of the Dresden Elbe Valley in 2004 (Decision 28 COM 14B.40 - Nominations of Cultural Properties to the World Heritage List (Dresden Elbe Valley 2004)
- The UNESCO de-listing of the Dresden Elbe Valley in 2009 (https://whc.unesco.org/en/list/1156, UNESCO World Heritage News 2009).

Properties:

HP16 initiated (was initiated by): HC10 Heritage Valuation

HP17 terminated (was terminated by): HC10 Heritage Valuation

HC13 Project

Subclass of: crm: E7 Activity

Superclass of:

Scope Note:

> The class comprises instances of collaborative enterprise activities over a period of time with the intention of producing outcomes/results according to a plan defined by a consortium or a responsible organization/group.

> An instance of a Project comes into being with the formation of an instance of a Group acting as a team whose aim it is to carry out and maintain the project.

> An instance of this class may be documented partially already at initiating time, i.e., the activity is expected to continue into the future. As work continues, the instance will accumulate more property instances until it is finished. Note that the future evolution may cause ambiguous identity conditions from some time on. At this point in time, the activity should be declared finished and be reinitiated unambiguously. (Therefore, activities expected to continue into the future are not in the scope of the CIDOC CRM in the narrower sense).

Examples:

- The ECHOES project 2024-2029
- The Ariadne project 2013-2017
- Projet Notre-Dame
- Projet ESPADON
- SilkNow

Properties:

HC14 Volatile Digital Object

Subclass of: crm: crmdig: D1 Digital Object

Equivalent to crmpem:PE20 Volatile Digital Object

Superclass of: HC2 Heritage Digital Twin

Scope Note:

> This class comprises instances of digital objects whose content is subject to continuous change, may be without notice or necessary archiving of intermediate state, but which can

be considered as one and the same with regards to its provenance, curating authority and some curation plan that determines its information, goal and subject coverage. The curating authority is responsible for assigning a unique identifier of an instance of HC14 Volatile Digital Object a link to its current content.

At any one point in time, the content of an instance of HC14 Volatile Digital Object can be identified with a snapshot of the current state of content, an instance of HC15 Persistent Digital Object, taken by the responsible curating authority. The latter constitutes a version of any previous snapshots taken from the same instance of HC14 Volatile Digital Object. The curator may assign a persistent identifier to an official snapshot and is the only individual who can identify a true representative snapshot.

Reference to the content of an instance of PE20 Volatile Digital Object is by way of official snapshots

Examples:

Properties:

HP28 has snapshot (is snapshot of): HC15 Persistent Digital Object

HP29 has digital object part: crmdig: D1 Digital Object

HC15 Persistent Digital Object

Subclass of: crmdig: D1 Digital Object

Equivalent to crmpe:PE19 Persistent Digital Object

Superclass of: HC16 Heritage Proposition Set

Scope Note:

This class comprises instances of digital object which are the result of a distinct creation moment in which the whole of the content of the digital object was established and encoded at a bit level, whether this creation moment is known or not.

Persistent digital objects are thus identified by their content, bit level encoding and the moment of production as a whole unit of information.

An instance of persistent digital object continues to exist as long as one copy of it remains on one carrier which has been maintained without change to its internal content, thus propagating the original condition of the instance.

.

Examples:

Properties:

HC16 Heritage Proposition Set

Subclass of: crminf: I4 Proposition Set

                HC15 Persistent Digital Object

Superclass of:

Scope Note:

The class comprises content units defined as sets of propositions that are formally encoded in a knowledge representation language. The identity of an instance of HC16 Heritage Proposition Set depends on the total of contained propositions, regardless of equivalent encodings.

In a Knowledge Base implementation, an instance of HC16 Heritage Proposition Set may be represented by the URI of a Named Graph comprising its propositions and/ or by an external file with a representative encoding of its content.

Examples:

Properties:

        HP32 replaced (was replaced by): HC16 Heritage Proposition Set

Sxx Observation with Inference

Subclass of:

        S27 Observation

        I5 Inference Making

Scope note:

This class comprises activities of making honest propositions and statements regarding material states of affairs of reality by making a directly related inference from the primary result of an observation.

This class is designed as a modelling convenience for the frequent case that the primary result of an observation is used in the same context of activity by the same Actor for an inference related to the purpose of the observation and providing in the

most relevant conclusion. Both the primary results and the conclusion should be expressed as sets of formal propositions regarded as true.

Besides all properties of I5 Inference Making being applicable to instances of this class, one of the premises implicitly links to the range of the instance of the property Oxx made primary observation: O27 Observable Situation as being true. Thereby, a complex connection between the observation and the inference is shortcut, without loosing the distinction of primary observation and direct interpretation, or worse, confusing it.

Examples:

In First Order Logic:

Properties:

> Oxx made primary observation (was observation of): S28 Observable Situation

5 HDTO Property Declaration

HP1 has digital twin (is digital twin of)

Domain: HC1 Heritage Entity

Range: HC2 Heritage Digital Twin

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property links an instance of HC1 Heritage Entity with an instance of its related HC2 Heritage Digital Twin in a given system. If a part of a Heritage Entity is described by an instance of Heritage Digital Twin, it implies that this instance of the Heritage Digital Twin is also part of the instance of the Heritage Digital Twin of the composite Heritage Entity.

Examples:

- The Pafos Gate in Nicosia, Cyprus (HC1) *has digital twin (HP1)* the Pafos Gate digital twin (HC2) created by Cyprus Institute.

HP2 has story (is story about)

Domain: HC1 Heritage Entity

Range: nont:Narrative

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property links an instance of HC1 Heritage Entity with an instance of a nont:Narrative that refers to it.

Examples:

- Falconry *has story (HP2)* the history of Falconry over the centuries.

HP3 is digital twin component of (has digital twin component)

Domain: HC2 Heritage Digital Twin

Range: HC2 Heritage Digital Twin

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property associates an instance of HC2 Heritage Digital Twin with another HC2 of which is component. The term 'component' here is not limited to physical or geographical relationships (see examples), but encompasses any kind of main-associated relationship.

Examples:

- The HC2 Digital Twin of Pafos Gate in Nicosia (Cyprus) *HP3 is a digital twin component of* the HC2 Digital Twin of Nicosias' City Walls.
- The HC2 Digital Twin of the "Cento Camini" Medici Villa in Artimino (Florence) *HP3 is a digital twin component of* the HC2 Digital Twin of the UNESCO WHS Medici Villas in Tuscany.
- The HC2 Digital Twin of Vichy is a *HP3 digital twin component of* the HC2 Digital Twin of the UNESCO WHS The Great Spa Towns of Europe
- The HC2 Digital Twin of the "Basilica of San Salvatore in Spoleto, Italy" is a *HP3 digital twin component of* the HC2 Digital Twin of "Spoleto", which is a HP3 digital twin component of the UNESCO WHS "Longobards in Italy. Places of Power".

HP4 narrates (is narrated through)

Domain: nont:Narration

Range: nont:Narrative

Subproperty of: crm:P148 has component.

Superproperty of:

Equivalent to nont: has narrative

Quantification:

Scope note: This property links an instance of nont:Narration, a subclass of Work in the sense of the FRBR model, with an instance of a nont:Narrative that constitutes a particular expression of it, in the sense of the FRBR model. It is equivalent to the nont:hasNarration property.

Examples:

- The "De Arte Venandi Cum Avibus" treatise by the Holy Roman Emperor Frederick II *narrates (HP4)* the history of Falconry.

HP5 has intangible heritage entity (is intangible heritage entity of)

Domain: HC3 Tangible Heritage Entity

Range: HC4 Intangible Heritage Entity

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property associates an instance of HC3 Tangible Heritage Entity with its intangible heritage entities (HC4), i.e. the cultural, social and historical value it incorporates

Examples:

- The "Theotokos of Vladimir" (HC3) icon *HP5 has intangible heritage entity* the secular veneration that is addressed to it (HC4).
- The UNESCO WHS site "Routes of Santiago de Compostela" (HC3) *has intangible heritage entity (HP5)* pilgrimage to Santiago (HC4).

HP6 has manifestation event (event is manifestation of)

Domain: HC4 Intangible Heritage Entity

Range: crm:E5 Event

Subproperty of: crm:P129 is about (is subject of)

Superproperty of:

Quantification:

Scope note: This property associates an instance of HC4 Intangible Heritage Entity with the instances of the crm:E5 Event (or of the unique and specific crm:E5 Event) through which the intangible entity manifests itself in the physical world

Examples:

- The Palio di Siena (HC4) *has manifestation event (HP6)* the historical horse race that was held in Siena on 17/8/2022 (E5)

HP7 is manifestation of (is manifested by)

Domain: HC3 Tangible Heritage Entity

Range: HC4 Intangible Heritage Entity

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property associates instances of HC3 Tangible Heritage Entity with the HC4 Intangible Heritage Entity of which they are the manifestation in the physical world

Examples:

- The set of devotional graffiti engraved on the walls of the Church of the Holy Sepulchre in Jerusalem (HC3) *is manifestation of (HP7)* the pilgrimage of which the church is the final destination (HC4)

HP8 is narrated in document (document used for narration)

Domain: nont:Narrative

Range: E90 Symbolic Object

Subproperty of:

Superproperty of:

Equivalent to nont: has text

Quantification:

Scope note: This property associates an instance of nont:Narrative with instances of E90 Symbolic Object that constitutes a particular version of it.

Examples:

- The "De Arte Venandi Cum Avibus" treatise by the Holy Roman Emperor Frederick II (nont:Narration) *is narrated in document (HP8)* the "MS. Lat. 419" manuscript, now in the library of the University of Bologna E31.

HP9 is visual representation of (has visual representation)

Domain: HC7 Digital Audiovisual Object

Range: crmsci:S15 Observable Entity

Subproperty of:

HC5 Digital Representation: HP22 represents (has digital representation): crmsci:S15 Observable Entity

Superproperty of:

Quantification:

Scope note: This property associates an instance of crmsci:S15 Observable Entity with instances of HC7 Digital Audiovisual Object in which it is visually represented.

This property expresses the digitisation of the heritage entity by the use of techniques such as digital photography, flatbed or infrared scanning.

Examples:

The Pisa Leaning Tower (S15) *has visual representation (HP9)* the Europeana digital version of the paper picture of the Pisa Leaning Tower taken by Paolo Monti in 1960

(https://www.europeana.eu/it/item/9200369/webclient_DeliveryManager_pid_6363979_c ustom_att_2_simple_viewer)

HP10 tells about (is told by)

Domain: nont:Narrative

Range: crm:E5 Event

Subproperty of: crm: P129 is about (is subject of)

Superproperty of:

Equivalent to inverse of nont: part of narrative

Quantification:

Scope note: This property associates an instance of nont:Narrative with a particular, actually or potentially real event that is reported in it.

Note that mythical events constitute instances of crm:E89 Propositional Objects that have no well defined identity in all their parts, but rather are represented by individual versions, according to each narrative, around a core of common propositions.

Examples:

"The history of Falconry (nont:Narrative) *tells about (HP10)* the writing of "De Arte Venandi Cum Avibus" treatise by the Holy Roman Emperor Frederick II (E5)

HP12 regards as origin (is regarded as origin by)

Domain: HC10 Heritage Valuation

Range: crm:E74 Group

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property links an instance of HC10 Heritage Valuation with an instance of E74 Group for which the valued Heritage Entity is regarded to constitute direct heritage, by originating, being created, valued and/or maintained in this Group.

Examples:

The valuation of the Al Aksa Mosque (HC10) *regards as origin (HP12)* Muslim worshippers (crm:E74 Group)

HP13 had target (was community for)

Domain: HC10 Heritage Valuation

Range: crm:E74 Group

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property links an instance of HC10 Heritage Valuation with an instance of E74 Group which is expected to value the respective entity as Heritage Entity following the declaration, in the case of UNESCO the nations under the UNO.

Examples:

HP14 values (is valued by)

Domain: HC10 Heritage Valuation

Range: HC1 Heritage Entity

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property links an instance of HC10 Heritage Valuation with an instance of a Heritage Entity the valuation is about.

Examples:

The valuation of the Dresden Elbe Valley in March 2004 by ICOMOS (HC10) *values (HP14)* the Dresden Elbe Valley (HC1) (ICOMOS, 2003).

HP15 is heritage of (has original heritage)

Domain: HC1 Heritage Entity

Range: crm:E74 Group

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property links an instance of HC1 Heritage Entity with an instance of E74 Group for which the valued Heritage Entity is regarded to constitute direct heritage, by originating, being created, valued and/or maintained in this Group.

This property is a shortcut for the fully developed path from HC1 Heritage Entity through *HP14i is valued by,* HC10 Heritage Valuation, *HP12i is regarded as origin by* to crm:E74 Group

Examples:

- The Dresden Elbe Valley (HC1) is heritage of (HP12) the population of Dresden (E74).
- The Pisa Leaning Tower (HP1) *is heritage of (HP12)* UNESCO World Heritage Listing.

HP16 initiated (was initiated by)

Domain: HC12 Heritage Declaration Event

Range: HC10 Heritage Valuation

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property links an instance of HC12 Heritage Declaration Event with an instance of HC10 Heritage Valuation that thereby begins the treatment of the valued entity as being of with heritage value.

Examples:

- The UNESCO listing of the Dresden Elbe Valley in 2004 (HC12) *initiated (HP16)* the valuation of the Dresden Elbe Valley in March 2004 (HC10)(Decision 28 COM 14B.40 - Nominations of Cultural Properties to the World Heritage List (Dresden Elbe Valley 2004).

HP17 terminated (was terminated by)

Domain: HC12 Heritage Declaration Event

Range: HC10 Heritage Valuation

Subproperty of:

Superproperty of:

Quantification:

Scope note: This property links an instance of HC12 Heritage Declaration Event with an instance of HC10 Heritage Valuation that thereby ends the treatment of the valued entity as being of heritage value.

Examples:

- The UNESCO de-listing of the Dresden Elbe Valley in 2009 (HC12) *terminated (HP17)* the valuation of the Dresden Elbe Valley in 2004 (HC10) (https://whc.unesco.org/en/list/1156, UNESCO World Heritage News 2009).

HP18 has documented (was documented by)

Domain: HC11 Digital Twin Maintenance

Range: HC1 Heritage Entity

Subproperty of:

 crm: E7 Activity. P16 used specific object (was used for): E70 Thing

Superproperty of:

Quantification:

 many to one, necessary (1,1:0,n)

Scope note: This property links an instance of HC11 Digital Twin Maintenance with an instance of a Heritage Entity that refers to.

Examples:

 The ECHOES Project team CNRS Digital Twin Maintenance (HC11) *has documented* (HP18) the Pafos Gate in Nicosia (HC1)

HP19 has composed (was composed by)

Domain: HC11 Digital Twin Maintenance

Range: HC2 Digital Twin

Subproperty of: crm:P94 has created (was created by): crm:E28 Conceptual Object

Superproperty of:

Quantification:

> many to one, necessary (1,1:0,n)

Scope note: This property links an instance of HC11 Digital Twin Maintenance with an instance of HC2 Digital Twin it has composed or complemented.

Examples:

> The ECHOES Project team CyI Maintenance (HC11) *has composed (HP19)* the HDT of the Pafos Gate in Nicosia (HC2)

HP20 was carried out under (had contribution)

Domain: HC11 Digital Twin Maintenance

Range: HC13 Project

Subproperty of: crm:E4 Period. P9i consists of (forms part of): crm:E4 Period

Superproperty of:

Quantification:

> many to one, necessary (1,1:0,n)

Scope note: This property links an instance of HC11 Digital Twin Maintenance with an instance of HC13 Project on behalf of which the documentation and maintenance was carried out.

Examples:

> The ECHOES Project team CNRS Maintenance (HC11) *was carried out under* the ECHOES project 2024-2029 (HC13).

HP21 is 3D representation output of (has 3D representation)

Domain: HC8 3D Model

Range: HC1 Heritage Entity

Subproperty of:

> HC5 Digital Representation: HP22 represents (has digital representation): crmsci:S15 Observable Entity

Superproperty of:

Quantification:

Scope note: This property associates an instance of HC1 Heritage Entity with instances of HC8 3D Model in which it is digitised and represented.

Examples:

HP22 represents (has digital representation)

Domain: HC5 Digital Representation

Range: crmsci:S15 Observable Entity

Subproperty of: crm: E36 Visual Item. P138 represents (has representation): E1 CRM Entity

Superproperty of:

> HC7 Digital Audiovisual Object: HP9 is visual representation of (has visual representation): crmsci:S15 Observable Entity

> HC8 3D Model: HP21 is 3D representation output of (has 3d representation): HC1 Heritage Entity

Quantification:

Scope note: This property associates an instance of crmsci:S15 Observable Entity with instances of HC5 Digital Representation in which it is digitally represented.

Examples:

HP23 was about (was subject of)

Domain: HC9 Study

Range: HC1 Heritage Entity

Subproperty of:

> crm: E7 Activity. P16 used specific object (was used for): E70 Thing

Superproperty of:

Quantification:

> many to many, necessary (1,n:0,n)

Scope note:

> This property associates an instance of HC9 Study with instances of HC1 Heritage Entity (their HC3 Tangible Heritage Entity and HC4 Intangible Heritage Entity) which were studied or related in relevant ways to a more specific item the study was actually about.

Examples:

- The multi-dimensional analysis and the memorization made during the restoration of Notre-Dame cathedral (HC9) HP23 has studied the Notre-Dame cathedral (HC1).

HP24 has disciplinary focus (is aspect of)

Domain: HC9 Study

Range: E55 Type

Subproperty of:

> E1 CRM Entity. P2 has type (is type of): E55 Type

Superproperty of:

Quantification:

many to many, necessary (1,n:0,n)

Scope note:

This property associates an instance of HC9 Study with the disciplinary aspect under which it investigated the respective heritage entities or related items, such as art conservation, history of art, C14 dating or anthropology.

Examples:

HP25 has created (was created by)

Domain: HC9 Study

Range: crm: E31 Document

Subproperty of:

crm: E65 Creation. P94 has created (was created by): E28 Conceptual Object

Superproperty of:

Quantification:

many to many, necessary (1,n:0,n)

Scope note:

This property associates an instance of HC9 Study with the resulting instance of E31 Document in a persistent ("fixed"), citable or at least permanently accessible form according to scholarly and scientific practice, independently from being represented partially or completely within an instance of HC2 Digital Twin.

Examples:

- The filming of archaeological activities (HC9) on the remains of the Sobibor extermination camp (HC3), *HP25 has created* the documentary film " Sheol " (HC7 or E73).

HP26 studied specifically (was studied by)

Domain: HC9 Study

Range: E1 CRM Entity

Subproperty of:

Superproperty of:

Quantification:

> many to many, necessary (0,n:0,n)

Scope note:

> This property associates an instance of HC9 Study with an item that was specifically investigated in this study and related in some way to the instances of HC1 Heritage Entity the study was about, such as instances of E39 Actor or E5 Event. This property should only be used, if the instance of HC1 Heritage Entity documented by the property HP23 was about (was subject of) was not the direct object of investigation.

Examples:

- The multi-dimensional analysis and the memorization made during the restoration of Notre-Dame cathedral (HC9) *HP23 has studied* the Notre-Dame cathedral (HC1).

HP27 used content of (content was used by)

Domain: HC11 Digital Twin Maintenance

Range: E31 Document

Subproperty of:

> crm: E7 Activity. P16 used specific object (was used for): E70 Thing

Superproperty of:

Quantification:

> many to many, necessary (1,n:0,n)

Scope note:

> This property associates an instance of HC11 Digital Twin Maintenance with an instance of E31 Document, typically results of an instance of HC9 Study, that were used for composing or complementing an instance of HC2 Heritage Digital Twin.

Examples:

- the creation of the HDT of the Tour de Choeur of Chartres cathedral (HC2), through the production of a resource page (HC6) and digital photographs (HC7) *HP27 used content of*

The study of the ornaments of the Tour de Coeur of Notre-Dame de Chartres cathedral realised during the ROSER project (E31).

HP28 has snapshot (is snapshot of)

Domain: HC14 Volatile Digital Object

Range: HC15 Persistent Digital Object

Subproperty of:

      crm: P130 shows features of (features are also found on

Superproperty of:

Equivalent to: crmpem: PP17 has snapshot (is snapshot of)

Quantification:

Scope note:

      This property associates an instance of HC14 Volatile Digital Object with an instance of HC15 Persistent Digital Object that captured the official content version of the volatile object at a particular point in time. The latter point in time is equal to the time of creation of the associated persistent object (as to be documented via an instance of E65 Creation or a subclass of it and its properties).

Examples:

HP29 has digital object part

Domain: HC14 Volatile Digital Object

Range: crmdig:D1 Digital Object

Subproperty of:

      crm: P106 is composed of (forms part of)

Superproperty of:

Equivalent to: crmpem: PP18 has digital object part (is digital object part of)

Quantification:

Scope note:

      This. property associates an instance of HC14 Volatile Digital Object with a structural part of that instance. This structural part may be another instance of D1 Digital object, be it also a HC14 Volatile Digital Object or in fact be an instance of HC15 Persistent Digital Object.

Examples:

HP30 added content (content was added by)

Domain: HC11 Digital Twin Maintenance

Range: HC16 Heritage Proposition Set

Subproperty of:

> crm: E7 Activity. P16 used specific object (was used for): E70 Thing

Superproperty of:

Quantification:

> many to many, necessary (1,n:0,n)

Scope note:

> This property associates an instance of HC11 Digital Twin Maintenance with an instance of HC16 Heritage Proposition Set that it has added to an instance of HC2 Digital Twin. In this way it composes or complements an instance of HC2 Heritage Digital Twin.

Examples:

HP31 deleted content (content was deleted by)

Domain: HC11 Digital Twin Maintenance

Range: HC16 Heritage Proposition Set

Subproperty of:

> crm: E7 Activity. P16 used specific object (was used for): E70 Thing

Superproperty of:

Quantification:

> many to many, necessary (1,n:0,n)

Scope note:

> This property associates an instance of HC11 Digital Twin Maintenance with an instance of HC16 Heritage Proposition Set that it has deleted from . Typically, this is done in a single action with adding one or more proposition sets that supersedes the deleted one. In this way it composes or complements an instance of HC2 Heritage Digital Twin.
>
> Note that the deletion only means to replace the property *HP33 contains (is proposition set of)* between the respective instance of HC2 Heritage Digital Twin and the "deleted" *proposition set* by the property *HP34 contained (if former proposition set of),* and not that the content unit has been purged from the archives.

Examples:

HP32 replaced (was replaced by)

Domain: HC16 Heritage Proposition Set

Range: HC16 Heritage Proposition Set

Subproperty of:

Superproperty of:

Quantification:

Scope note:

> This property associates an instance of HC16 Heritage Proposition Set with an instance of HC16 Heritage Proposition Set, that was replaced by it in some instance of HC2 Heritage Digital Twin. In more detail, if an instance of HC11 Digital Twin Maintenance added a *proposition set* via *HP30 added content (content was added*) and deleted another one via *HP31 deleted content (content was deleted by)* from a Digital Twin, this property allows for documenting that the deleted one is replaced by the former, i.e., constitutes a version that is no more valid.

> This property allows for documenting directly a chain of previous versions of some *proposition sets*, starting from the most recent one. The latter should be associated with the property *HP33 contains (is proposition set of)* to the respective instance of HC2 Heritage Digital Twin for which it is currently valid. All other *proposition set* in the same chain of versions should be associated with the property *HP34 contained (if former proposition set of)* to the respective instance of HC2 Heritage Digital Twin for which they had been previously valid.

Examples:

HP33 contains (is proposition set of)

Domain: HC2 Heritage Digital Twin

Range: HC16 Heritage Proposition Set

Subproperty of:

Superproperty of:

Quantification:

Scope note:

> This property associates an instance of HC2 Heritage Digital Twin with an instance of HC16 Heritage Proposition Set that constitutes a currently valid part of its content.

Examples:

HP34 contained (is former proposition set of)

Domain: HC2 Heritage Digital Twin
Range: HC16 Heritage Proposition Set
Subproperty of:
Superproperty of:

Quantification:
Scope note:

> This property associates an instance of HC2 Heritage Digital Twin with an instance of HC16 Heritage Proposition Set that constituted a former, now no more valid part of its content. This property is necessary to maintain referential integrity for scholarly references to previous content of this instance of HC2 Heritage Digital Twin.

Examples:

OXX made primary observation (was observation of)

Domain: Sxx Observation with Inference
Range: S28 Observable Situation
Subproperty of: S27 Observation. O36 expressed the observed as (was the expression of): S28 Observable Situation
Superproperty of:

Quantification:
Scope note:

> This property associates an instance of Sxx Observation with Inference with an instance of S28 Observable Situation that constitutes the expression of the primary observation and premise for the following implicit inference by the actors carrying out the respective activity. The alleged time-span of validity of the observed situation must be equal or within the overall time-span of the domain instance used for this property. A narrower time-span of validity for the observed situation can be documented via the property S28 Observable Situation. J24 held at least for (is at least validity of): E52 Time-Span

Examples:

6 References

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7 Appendix

8 Referred CIDOC CRM Classes and Properties

Since our model refers to and reuses, wherever appropriate, large parts of ISO21127, the CIDOC Conceptual Reference Model, this section provides a comprehensive list of all constructs used from ISO21127, together with their definitions following version 7.3 maintained by CIDOC. The complete definition of the CIDOC Conceptual Reference Model can be found in its official site: http://www.cidoc-crm.org/official_release_cidoc.html.

8.1 Referred CIDOC CRM Classes

This section contains the complete definitions of the classes of the CIDOC CRM Conceptual Reference Model version 7.3 referred to by the model.

E1 CRM Entity

Superclass of:

> E2 Temporal Entity
> E52 Time-Span
> E53 Place
> E54 Dimension
> E59 Primitive Value
> E77 Persistent Item
> E92 Spacetime Volume

Scope note:

> This class comprises all things in the universe of discourse of the CIDOC Conceptual Reference Model.
>
> It is an abstract concept providing for three general properties:
>
> - Identification by name or appellation, and in particular by a preferred identifier
> - Classification by type, allowing further refinement of the specific subclass an instance belongs to

- Attachment of free text and other unstructured data for the expression of anything not captured by formal properties

All other classes within the CIDOC CRM are directly or indirectly specialisations of E1 CRM Entity.

Examples:

o the earthquake in Lisbon 1755 (E5) (Chester, 2001)

In first-order logic:

E1(x)

Properties:

P1 is identified by (identifies): E41 Appellation
P2 has type (is type of): E55 Type
P3 has note: E62 String
      (P3.1 has type: E55 Type)
P48 has preferred identifier (is preferred identifier of): E42 Identifier
P137 exemplifies (is exemplified by): E55 Type
      (P137.1 in the taxonomic role: E55 Type)

E2 Temporal Entity

Subclass of:

E1 CRM Entity

Superclass of:

E3 Condition State
E4 Period

Scope note:

This class comprises all phenomena, such as the instances of E4 Periods and E5 Events, which happen over a limited extent in time. This extent in time must be contiguous, i.e., without gaps. In case the defining kinds of phenomena for an instance of E2 Temporal Entity cease to happen, and occur later again at another time, we regard that the former instance of E2 Temporal Entity has ended and a new instance has come into existence. In more intuitive terms, the same event cannot happen twice.

In some contexts, such phenomena are also called perdurants. This class is disjoint from E77 Persistent Item and is an abstract class that typically has no direct instances. E2 Temporal Entity is specialized into E4 Period, which applies to a particular geographic area (defined with a greater or lesser degree of precision), and E3 Condition State, which applies to instances of E18 Physical Thing.

Examples:

- o Bronze Age (E4) (Childe, 1963)
- o the earthquake in Lisbon 1755 (E5) (Chester, 2001)
- o the Peterhof Palace near Saint Petersburg being in ruins from 1944 – 1946 (E3) (Maddox, 2015)

In first-order logic:

E2(x) ⇒ E1(x)

Properties:

P4 has time-span (is time-span of): E52 Time-Span

P173 starts before or with the end of (ends after or with the start of): E2 Temporal Entity

P174 starts before the end of (ends after the start of): E2 Temporal Entity

P175 starts before or with the start of (starts after or with the start of): E2 Temporal Entity

P176 starts before the start of (starts after the start of): E2 Temporal Entity

P182 ends before or with the start of (starts after or with the end of): E2 Temporal Entity

P183 ends before the start of (starts after the end of): E2 Temporal Entity

P184 ends before or with the end of (ends with or after the end of): E2 Temporal Entity

P185 ends before the end of (ends after the end of): E2 Temporal Entity

E4 Period

Subclass of:

E2 Temporal Entity
E92 Spacetime Volume

Superclass of:

E5 Event

Scope note:

This class comprises sets of coherent phenomena or cultural manifestations occurring in time and space.

It is the social or physical coherence of these phenomena that identify an instance of E4 Period and not the associated spatiotemporal extent. This extent is only the "ground" or space in an abstract physical sense that the actual process of growth, spread and retreat has covered. Consequently, different periods can overlap and

coexist in time and space, such as when a nomadic culture exists in the same area and time as a sedentary culture. This also means that overlapping land use rights, common among first nations, amounts to overlapping periods.

Often, this class is used to describe prehistoric or historic periods such as the "Neolithic Period", the "Ming Dynasty" or the "McCarthy Era", but also geopolitical units and activities of settlements are regarded as special cases of E4 Period. However, there are no assumptions about the scale of the associated phenomena. In particular all events are seen as synthetic processes consisting of coherent phenomena. Therefore, E4 Period is a superclass of E5 Event. For example, a modern clinical birth, an instance of E67 Birth, can be seen as both a single event, i.e., an instance of E5 Event, and as an extended period, i.e., an instance of E4 Period, that consists of multiple physical processes and complementary activities performed by multiple instances of E39 Actor.

As the actual extent of an instance of E4 Period in spacetime we regard the trajectories of the participating physical things during their participation in an instance of E4 Period. This includes the open spaces via which these things have interacted and the spaces by which they had the potential to interact during that period or event in the way defined by the type of the respective period or event. Examples include the air in a meeting room transferring the voices of the participants. Since these phenomena are fuzzy, we assume the spatiotemporal extent to be contiguous, except for cases of phenomena spreading out over islands or other separated areas, including geopolitical units distributed over disconnected areas such as islands or colonies.

Whether the trajectories necessary for participants to travel between these areas are regarded as part of the spatiotemporal extent or not has to be decided in each case based on a concrete analysis, taking use of the sea for other purposes than travel, such as fishing, into consideration. One may also argue that the activities to govern disconnected areas imply travelling through spaces connecting them and that these areas hence are spatially connected in a way, but it appears counterintuitive to consider for instance travel routes in international waters as extensions of geopolitical units.

Consequently, an instance of E4 Period may occupy a number of disjoint spacetime volumes, however there must not be a discontinuity in the timespan covered by these spacetime volumes. This means that an instance of E4 Period must be contiguous in time. If it has ended in all areas, it has ended as a whole. However, it may end in one area before another, such as in the Polynesian migration, and it continues as long as it is ongoing in at least one area.

We model E4 Period as a subclass of E2 Temporal Entity and of E92 Spacetime Volume. The latter is intended as a phenomenal spacetime volume as defined in CIDOC CRMgeo (Doerr & Hiebel, 2013). By virtue of this multiple inheritance, we can discuss the physical extent of an instance of E4 Period without representing each instance of it together with an instance of its associated spacetime volume. This model combines two quite different kinds of substance: an instance of E4 Period is a phenomenon while an instance of E92 Spacetime Volume is an aggregation of points in spacetime. However, the real spatiotemporal extent of an instance of E4 Period is regarded to be unique to it due to all its details and fuzziness; its identity and existence depends uniquely on the identity of the instance of E4 Period. Therefore, this multiple inheritance is unambiguous and effective and furthermore corresponds to the intuitions of natural language.

Typical use of this class in cultural heritage documentation is for documenting cultural and artistic periods. There are two different conceptualisations of 'artistic style', defined either by physical features or by historical context. For example, "Impressionism" can be viewed as a period in the European sphere of influence lasting from approximately 1870 to 1905 during which paintings with particular characteristics were produced by a group of artists that included (among others) Monet, Renoir, Pissarro, Sisley and Degas. Alternatively, it can be regarded as a style applicable to all paintings sharing the characteristics of the works produced by the Impressionist painters, regardless of historical context. The first interpretation is an instance of E4 Period, and the second defines morphological object types that fall under E55 Type.

A geopolitical unit as a specific case of an instance of E4 Period is the set of activities and phenomena related to the claim of power, the consequences of belonging to a jurisdictional area and an administrative system that establishes a geopolitical unit. Examples from the modern period are countries or administrative areas of countries such as districts whose actions and structures define activities and phenomena in the area that they intend to govern. The borders of geopolitical units are often defined in contracts or treaties although they may deviate from the actual practice. The spatiotemporal properties of Geopolitical units can be modelled through the properties inherited from E92 Spacetime Volume.

Another specific case of an instance of E4 Period is the actual extent of the set of activities and phenomena as evidenced by their physical traces that define a settlement, such as the populated period of Nineveh.

Examples:

   o Jurassic (Hallam, 1975)

- o Populated Period of Nineveh
- o Imperial Rome under Marcus Aurelius
- o European Bronze Age (Harrison, 2004)
- o Italian Renaissance (Macdonald, 1992)
- o Thirty Years War (Lee, 1991)
- o Sturm und Drang (Berkoff, 2013)
- o Cubism (Cox, 2000)
- o The Capital of Russia (E4) [the capital of Russia in the sense of an administrative unit moved in historical times from Moscow to St Petersburg and then back to Moscow. This exemplifies an administrative unit changing place over time without temporal discontinuity]
- o The settling activity of the community of Helsinki (a.k.a. Helsingfors) (E7) [the original settlement called Helsinki was located in the area of the modern airport. The community moved later to settle on the coast. This exemplifies a continued activity changing place over time without temporal discontinuity]
- o Bronze Age (E4) [Bronze Age, in the sense of technological adoption, spread over disjoint areas including islands such as the British Isles without temporal discontinuity]
- o Japan, the state (E4) [In 2021, the Japanese state as a political unit comprised in 6852 islands extending along the Pacific coast of Asia]

In first-order logic:

$$E4(x) \Rightarrow E2(x)$$
$$E4(x) \Rightarrow E92(x)$$

Properties:

P7 took place at (witnessed): E53 Place
P8 took place on or within (witnessed): E18 Physical Thing
P9 consists of (forms part of): E4 Period

E5 Event

Subclass of:

E4 Period

Superclass of:

E7 Activity
E63 Beginning of Existence
E64 End of Existence

Scope note:

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.

While the continuous growth of a tree lacks the limits characteristic of an event, its germination from a seed does qualify as an event. Similarly, the blowing of the wind lacks the distinctness and limits of an event, but a hurricane, flood or earthquake would qualify as an event. Mental processes are considered as events, in cases where they are connected with the material externalization of their results; for example, the creation of a poem, a performance or a change of intention that becomes obvious from subsequent actions or declarations.

The effects of an instance of E5 Event may not lead to relevant permanent changes of properties or relations of the items involved in it, for example an unrecorded performance. Of course, in order to be documented, some kind of evidence for an event must exist, be it witnesses, traces or products of the event.

While instances of E4 Period always require some form of coherence between its constituent phenomena, in addition, the essential constituents of instances of E5 Event should contribute to an overall effect; for example, the statements made during a meeting and the listening of the audience.

Viewed at a coarse level of detail, an instance of E5 Event may appear as if it had an 'instantaneous' overall effect, but any process or interaction of material nature in reality have an extent in time and space. At a fine level, instances of E5 Event may be analysed into component phenomena and phases within a space and timeframe, and as such can be seen as a period, regardless of the size of the phenomena. The reverse is not necessarily the case: not all instances of E4 Period give rise to a noteworthy overall effect and are thus not instances of E5 Event.

Examples:

o the birth of Cleopatra (E67) (Pomeroy, 1984)
o the destruction of Herculaneum by volcanic eruption in 79 AD (E6) (Camardo, 2013)
o World War II (E7) (Barber, 1994)
o the Battle of Stalingrad (E7) (Hoyt, 1993)
o the Yalta Conference (E7) (Harbutt, 2010)

  o my birthday celebration 28-6-1995 (E7)

  o the falling of a tile from my roof last Sunday (fictitious)

  o the CIDOC conference 2003 (E7)

In first-order logic:

  E5(x) ⇒ E4(x)

Properties:

  P11 had participant (participated in): E39 Actor

  P12 occurred in the presence of (was present at): E77 Persistent Item

E7 Activity

Subclass of:

  E5 Event

Superclass of:

  E8 Acquisition

  E9 Move

  E10 Transfer of Custody

  E11 Modification

  E13 Attribute Assignment

  E65 Creation

  E66 Formation

  E85 Joining

  E86 Leaving

  E87 Curation Activity

Scope note:

  This class comprises actions intentionally carried out by instances of E39 Actor that result in changes of state in the cultural, social, or physical systems documented.

  This notion includes complex, composite and long-lasting actions such as the building of a settlement or a war, as well as simple, short-lived actions such as the opening of a door.

Examples:

  o the Battle of Stalingrad (Hoyt, 1993)

  o the Yalta Conference (Harbutt, 2010)

  o my birthday celebration 28-6-1995

  o the writing of "Faust" by Goethe (E65) (Williams, 2020)

  o the formation of the Bauhaus 1919 (E66) (Droste, 2006)

o calling the place identified by TGN '7017998' 'Quyunjig' by the people of Iraq
o Kira Weber working in glass art from 1984 to 1993 (Weber, 2012)
o Kira Weber working in oil and pastel painting from 1993 up to present (Weber, 2012)

In first-order logic:

E7(x) ⇒ E5(x)

Properties:

P14 carried out by (performed): E39 Actor
(P14.1 in the role of: E55 Type)
P15 was influenced by (influenced): E1 CRM Entity
P16 used specific object (was used for): E70 Thing
(P16.1 mode of use: E55 Type)
P17 was motivated by (motivated): E1 CRM Entity
P19 was intended use of (was made for): E71 Human-Made Thing
(P19.1 mode of use: E55 Type)
P20 had specific purpose (was purpose of): E5 Event
P21 had general purpose (was purpose of): E55 Type
P32 used general technique (was technique of): E55 Type
P33 used specific technique (was used by): E29 Design or Procedure
P125 used object of type (was type of object used in): E55 Type
P134 continued (was continued by): E7 Activity

E13 Attribute Assignment

Subclass of:

E7 Activity

Superclass of:

E14 Condition Assessment
E15 Identifier Assignment
E16 Measurement
E17 Type Assignment

Scope note:

This class comprises the actions of making assertions about one property of an object or any single relation between two items or concepts. The type of the property asserted to hold between two items or concepts can be described by the property *P177 assigned property of type (is type of property assigned)*: E55 Type.

For example, the class describes the actions of people making propositions and statements during certain scientific/scholarly procedures, e.g., the person and date when a condition statement was made, an identifier was assigned, the museum object was measured, etc. Which kinds of such assignments and statements need to be documented explicitly in structures of a schema rather than free text, depends on whether this information should be accessible by structured queries.

This class allows for the documentation of how the respective assignment came about, and whose opinion it was. Note that all instances of properties described in a knowledge base are the opinion of someone. Per default, they are the opinion of the team maintaining the knowledge base. This fact must not individually be registered for all instances of properties provided by the maintaining team, because it would result in an endless recursion of whose opinion was the description of an opinion. Therefore, the use of instances of E13 Attribute Assignment marks the fact that the maintaining team is in general neutral to the validity of the respective assertion, but registers someone else's opinion and how it came about.

All properties assigned in such an action can also be seen as directly relating the respective pair of items or concepts. Multiple use of instances of E13 Attribute Assignment may possibly lead to a collection of contradictory values.

Examples:

- o the examination of MS Sinai Greek 418 by Nicholas Pickwoad in November 2003 (Honey & Pickwoad, 2010)
- o the assessment of the current ownership of Martin Doerr's silver cup in February 1997 (fictitious)

In first-order logic:

E13(x) ⇒ E7(x)

Properties:

P140 assigned attribute to (was attributed by): E1 CRM Entity
P141 assigned (was assigned by): E1 CRM Entity
P177 assigned property of type (is type of property assigned): E55 Type

E18 Physical Thing

Subclass of:

E72 Legal Object

Superclass of:

> E19 Physical Object
> E24 Physical Human-Made Thing
> E26 Physical Feature

Scope note:

> This class comprises all persistent physical items with a relatively stable form, human-made or natural.

> Depending on the existence of natural boundaries of such things, the CIDOC CRM distinguishes the instances of E19 Physical Object from instances of E26 Physical Feature, such as holes, rivers, pieces of land etc. Most instances of E19 Physical Object can be moved (if not too heavy), whereas features are integral to the surrounding matter.

> An instance of E18 Physical Thing occupies not only a particular geometric space at any instant of its existence, but in the course of its existence it also forms a trajectory through spacetime, which occupies a real, that is phenomenal, volume in spacetime. We include in the occupied space the space filled by the matter of the physical thing and all its inner spaces, such as the interior of a box. For the purpose of more detailed descriptions of the presence of an instance of E18 Physical Thing in space and time it can be associated with its specific instance of E92 Spacetime Volume by the property *P196 defines (is defined by).*

> The CIDOC CRM is generally not concerned with amounts of matter in fluid or gaseous states, as long as they are not confined in an identifiable way for an identifiable minimal time-span.

Examples:

> o the Cullinan Diamond (E19) (Scarratt and Shor, 2006)
> o the cave "Ideon Andron" in Crete (E26) (Smith, 1844-49)
> o the Mona Lisa (E22) (Mohen, 2006)

In first-order logic:

> E18(x) ⇒ E72(x)

Properties:

> P44 has condition (is condition of): E3 Condition State
> P45 consists of (is incorporated in): E57 Material
> P46 is composed of (forms part of): E18 Physical Thing
> P49 has former or current keeper (is former or current keeper of): E39 Actor
> P50 has current keeper (is current keeper of): E39 Actor

P51 has former or current owner (is former or current owner of): E39 Actor

P52 has current owner (is current owner of): E39 Actor

P53 has former or current location (is former or current location of): E53 Place

P59 has section (is located on or within): E53 Place

P128 carries (is carried by): E90 Symbolic Object

P156 occupies (is occupied by): E53 Place

P196 defines (is defined by): E92 Spacetime Volume

E28 Conceptual Object

Subclass of:

> E71 Human-Made Thing

Superclass of:

> E55 Type
> E89 Propositional Object
> E90 Symbolic Object

Scope note:

> This class comprises non-material products of our minds and other human produced data that have become objects of a discourse about their identity, circumstances of creation or historical implication. The production of such information may have been supported by the use of technical devices such as cameras or computers.

> Characteristically, instances of this class are created, invented or thought by someone, and then may be documented or communicated between persons. Instances of E28 Conceptual Object have the ability to exist on more than one particular carrier at the same time, such as paper, electronic signals, marks, audio media, paintings, photos, human memories, etc.

> They cannot be destroyed. They exist as long as they can be found on at least one carrier or in at least one human memory. Their existence ends when the last carrier and the last memory are lost.

Examples:

> o Beethoven's "Ode an die Freude" (Ode to Joy) (E73) (Kershaw, 1999)
> o the definition of "ontology" in the Oxford English Dictionary (E73) (Oxford University Press, 1989)
> o the knowledge about the victory at Marathon carried by the famous runner (E89) (Lagos & Karyanos, 2020)

[Explanation note: In the following examples we illustrate the distinction between a propositional object, its names and its encoded forms. The Maxwell equations (Ball, 1962) are a good example, because they belong to the fundamental laws of physics and their mathematical content yields identical, unambiguous results regardless formulation and encoding.]

o "Maxwell equations" (E41) [preferred subject access point from LCSH, http://lccn.loc.gov/sh85082387, accessed 18 April 2021. This is only the name for the Maxwell equations as standardized by the Library of Congress and not the equations themselves.]

o "Equations, Maxwell" (E41) [variant subject access point from LCSH, http://lccn.loc.gov/sh85082387, accessed 18 April 2021. This is another name for the equation standardized by the Library of Congress and not the equations themselves.]

o Maxwell's equations (E89) [This is the propositional content of the equations proper, independent of any particular notation or mathematical formalism.] (Ball, 1962)

o The encoding of Maxwell's equations as in https://upload.wikimedia.org/wikipedia/commons/c/c4/Maxwell%27sEquations.svg (E73) [accessed 18 April 2021. This is one possible symbolic encoding of the propositional content of the equations.]

In first-order logic:

$E28(x) \Rightarrow E71(x)$

E31 Document

Subclass of:

E73 Information Object

Superclass of:

E32 Authority Document

Scope note:

This class comprises identifiable immaterial items that make propositions about reality.

These propositions may be expressed in text, graphics, images, audiograms, videograms or by other similar means. Documentation databases are regarded as instances of E31 Document. This class should not be confused with the concept

"document" in Information Technology, which is compatible with E73 Information Object.

Examples:

- o the Encyclopaedia Britannica (E32) (Kogan, 1958)
- o the image content of the photo of the Allied Leaders at Yalta published by UPI, 1945 (E36)
- o Domesday Book [a manuscript record of the "Great Survey" of much of England and parts of Wales completed in 1086 by order of King William the Conqueror] (Hallam 1986)

In first-order logic:

E31(x) ⇒ E73(x)

Properties:

P70 documents (is documented in): E1 CRM Entity

E36 Visual Item

Subclass of:

E73 Information Object

Superclass of:

E37 Mark

Scope note:

This class comprises the intellectual or conceptual aspects of recognisable marks, images and other visual works.

This class does not intend to describe the idiosyncratic characteristics of an individual physical embodiment of a visual item, but the underlying prototype. For example, a mark such as the ICOM logo is generally considered to be the same logo when used on any number of publications. The size, orientation and colour may change, but the logo remains uniquely identifiable. The same is true of images that are reproduced many times. This means that visual items are independent of their physical support.

The class E36 Visual Item provides a means of identifying and linking together instances of E24 Physical Human-Made Thing that carry the same visual qualities (symbols, marks or images etc.). The property *P62 depicts (is depicted by)* between E24 Physical Human-Made Thing and depicted subjects (E1 CRM Entity) is a shortcut of the more fully developed path from E24 Physical Human-Made Thing through *P65 shows*

visual item (is shown by), E36 Visual Item, *P138 represents (has representation)* to E1 CRM Entity, which in addition captures the optical features of the depiction.

Examples:

- o the visual appearance of Monet's "La Pie" (Bortolatto, 1981)
- o the Coca-Cola logo (E34)
- o the Chi-Rho (E37)
- o the communist red star (E37)
- o the surface shape of Auguste Rodin's statue "Le Penseur" [there exist more than 20 copies, even of different size. Therefore, this is a good example that it is only the common surface shape, an immaterial visual item, which justifies displaying these copies as works of Auguste Rodin. As usual practice, Rodin himself did not produce the bronze statue, but only the prototype model.]

In first-order logic:

E36(x) ⇒ E73(x)

Properties:

P138 represents (has representation): E1 CRM Entity
(P138.1 mode of representation: E55 Type)

E39 Actor

Subclass of:

E77 Persistent Item

Superclass of:

E21 Person
E74 Group

Scope note:

This class comprises people, either individually or in groups, who have the potential to perform intentional actions of kinds for which someone may be held responsible.

Examples:

- o London and Continental Railways (E74)
- o the Governor of the Bank of England in 1975 (E21)
- o Sir Ian McKellen (E21) (Gibson, 1986)

In first-order logic:

E39(x) ⇒ E77(x)

Properties:

P74 has current or former residence (is current or former residence of): E53 Place

P75 possesses (is possessed by): E30 Right

P76 has contact point (provides access to): E41 Appellation

E55 Type

Subclass of:

E28 Conceptual Object

Superclass of:

E56 Language

E57 Material

E58 Measurement Unit

E99 Product Type

Scope note:

This class comprises concepts denoted by terms from thesauri and controlled vocabularies used to characterize and classify instances of CIDOC CRM classes. Instances of E55 Type represent concepts in contrast to instances of E41 Appellation which are used to name instances of CIDOC CRM classes.

E55 Type is the CIDOC CRM's interface to domain specific ontologies and thesauri. These can be represented in the CIDOC CRM as subclasses of E55 Type, forming hierarchies of terms, i.e., instances of E55 Type linked via *P127 has broader term (has narrower term)*: E55 Type. Such hierarchies may be extended with additional properties.

Examples:

o weight, length, depth [types for instances of E54]

o portrait, sketch, animation [types for instances of E36]

o French, English, German (E56)

o excellent, good, poor [types for instances of E3]

o Ford Model T, chop stick [types for instances of E22]

o cave, doline, scratch [types for instances of E26]

o poem, short story [types for instances of E33]

o wedding, earthquake, skirmish [types for instances of E5]

In first-order logic:

$E55(x) \Rightarrow E28(x)$

Properties:

> P127 has broader term (has narrower term): E55 Type
> P150 defines typical parts of (define typical wholes for): E55 Type

E65 Creation

Subclass of:

> E7 Activity
> E63 Beginning of Existence

Superclass of:

> E83 Type Creation

Scope note:

> This class comprises events that result in the creation of conceptual items or immaterial products, such as legends, poems, texts, music, images, movies, laws, types etc.

Examples:

> o the framing of the U.S. Constitution (Farrand, 1913)
> o the drafting of U.N. resolution 1441 (United Nations Security Council, 2002)

In first-order logic:

> E65(x) ⇒ E7(x)
> E65(x) ⇒ E63(x)

Properties:

> P94 has created (was created by): E28 Conceptual Object

E70 Thing

Subclass of:

> E77 Persistent Item

Superclass of:

> E71 Human-Made Thing
> E72 Legal Object

Scope note:

This general class comprises discrete, identifiable, instances of E77 Persistent Item that are documented as single units, that either consist of matter or depend on being carried by matter and are characterized by relative stability.

They may be intellectual products or physical things. They may for instance have a solid physical form, an electronic encoding, or they may be a logical concept or structure.

Examples:

- o my photograph collection (E78) (fictitious)
- o the bottle of milk in my refrigerator (E22) (fictitious)
- o the Riss A1 plan of the Straßburger Münster (French: Cathédrale Notre-Dame de Strasbourg) (E29) (Liess, R., 1985)
- o the thing on the top of Otto Hahn's desk (E19)
- o the form of the no-smoking sign (E36)
- o the cave of Dirou, Mani, Greece (E26) (Psimenos, 2005)

In first-order logic:

$$E70(x) \Rightarrow E77(x)$$

Properties:

P43 has dimension (is dimension of): E54 Dimension
P101 had as general use (was use of): E55 Type
P130 shows features of (features are also found on): E70 Thing
      (P130.1 kind of similarity: E55 Type)

E74 Group

Subclass of:

E39 Actor

Scope note:

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. In the wider sense this class also comprises official positions which used to be regarded in certain contexts as one actor, independent of the current holder of the office, such as the president of a country. In such cases, it may happen that the group never had more than one member. A joint pseudonym (i.e., a name that seems indicative of an

individual but that is actually used as a persona by two or more people) is a particular case of E74 Group.

A gathering of people becomes an instance of E74 Group when it exhibits organizational characteristics usually typified by a set of ideas or beliefs held in common, or actions performed together. These might be communication, creating some common artifact, a common purpose such as study, worship, business, sports, etc. Nationality can be modelled as membership in an instance of E74 Group. Married couples and other concepts of family are regarded as particular examples of E74 Group.

Examples:

- o the impressionists (Wilson, 1994)
- o the Navajo (Correll, 1972)
- o the Greeks (Williams, 1993)
- o the peace protestors in New York City on 15th February 2003
- o Exxon-Mobil (Raymond, 2006)
- o King Solomon and his wives (Thieberger, 1947)
- o the President of the Swiss Confederation
- o Nicolas Bourbaki [the collective pseudonym of a group of mathematicians, predominantly French alumni of the École normale supérieure] (Aczel, 2007)
- o Betty Crocker (Crocker, 2012)
- o Ellery Queen [Ellery Queen is a pseudonym created in 1929 by American crime fiction writers Frederic Dannay and Manfred Bennington Lee.] (Wheat, 2005)
- o Greenpeace
- o Paveprime Ltd
- o the National Museum of Denmark

In first-order logic:

$$E74(x) \Rightarrow E39(x)$$

Properties:

P107 has current or former member (is current or former member of): E39 Actor
(P107.1 kind of member: E55 Type)

E89 Propositional Object

Subclass of:

E28 Conceptual Object

Superclass of:

E73 Information Object
E30 Right

Scope note:

This class comprises immaterial items, including but not limited to stories, plots, procedural prescriptions, algorithms, laws of physics or images that are, or represent in some sense, sets of propositions about real or imaginary things and that are documented as single units or serve as topic of discourse.

This class also comprises items that are "about" something in the sense of a subject. In the wider sense, this class includes expressions of psychological value such as non-figural art and musical themes. However, conceptual items such as types and classes are not instances of E89 Propositional Object. This should not be confused with the definition of a type, which is indeed an instance of E89 Propositional Object.

Examples:

o Maxwell's Equations (Ball, 1962)
o the ideational contents of Aristotle's book entitled 'Metaphysics' as rendered in the Greek texts translated in Oxford edition
o the underlying prototype of any "no-smoking" sign (E36)
o the common ideas of the plots of the movie "The Seven Samurai" by Akira Kurosawa and the movie "The Magnificent Seven" by John Sturges (Mellen, 2002)
o the image content of the photo of the Allied Leaders at Yalta published by UPI, 1945 (E36)
o the character "Little Red Riding Hood", variants of which appear amongst others in Grimm brothers' 'Rotkäppchen', other oral fairy tales and the film 'Hoodwinked'
o the place "Havnor" as invented by Ursula K. Le Guin for her 'Earthsea' book series, the related maps and appearing in derivative works based on these novels

In first-order logic:

$$E89(x) \Rightarrow E28(x)$$

Properties:

P67 refers to (is referred to by): E1 CRM Entity
    (P67.1 has type: E55 Type)
P129 is about (is subject of): E1 CRM Entity
P148 has component (is component of): E89 Propositional Object

E90 Symbolic Object

Subclass of:

> E28 Conceptual Object
> E72 Legal Object

Superclass of:

> E73 Information Object
> E41 Appellation

Scope note:

> This class comprises identifiable symbols and any aggregation of symbols, such as characters, identifiers, traffic signs, emblems, texts, data sets, images, musical scores, multimedia objects, computer program code or mathematical formulae that have an objectively recognizable structure and that are documented as single units.

> It includes sets of signs of any nature, which may serve to designate something, or to communicate some propositional content. An instance of E90 Symbolic Object may or may not have a specific meaning, for example an arbitrary character string.

> In some cases, the content of an instance of E90 Symbolic Object may completely be represented by a serialized digital content model, such as a sequence of ASCII-encoded characters, an XML or HTML document, or a TIFF image. The property P3 has note and its subproperty P190 has symbolic content allow for the description of this content model. In order to disambiguate which symbolic level is the carrier of the meaning, the property P3.1 has type can be used to specify the encoding (e.g., "bit", "Latin character", RGB pixel).

Examples:

> - 'ecognizabl'
> - the "no-smoking" sign (E36)
> - "BM000038850.JPG" (E41) [identifies a digital image] (Natural History Museum, 2021)
> - image BM000038850.JPG from the Clayton Herbarium in London (E36) [depicts specimen of Verbesina virginica] (Natural History Museum, 2021)
> - the distribution of form, tone and colour found on Leonardo da Vinci's painting named "Mona Lisa" in daylight (E36)
> - the Italian text of Dante's "Divina Commedia" as found in the authoritative critical edition La Commedia secondo l'antica vulgata a cura di Giorgio Petrocchi, Milano: Mondadori, 1966-67 (= Le Opere di Dante Alighieri, Edizione Nazionale a cura della Società Dantesca Italiana, VII, 1-4) (E33) (Petrocchi, 1967)

In first-order logic:

E90(x) ⇒ E28(x)

E90(x) ⇒ E72(x)

Properties:

P106 is composed of (forms part of): E90 Symbolic Object

P190 has symbolic content: E62 String

8.2 Referred CIDOC CRM Properties

This section contains the complete definitions of the properties of the CIDOC CRM Conceptual Reference Model version 7.3 referred to.

P2 has type (is type of)

Domain:

E1 CRM Entity

Range:

E55 Type

Superproperty of:

E1 CRM Entity. P137 exemplifies (is exemplified by): E55 Type

E13 Attribute Assignment. P177 assigned property of type (is property assigned): E55 Type

Quantification:

many to many (0,n:0,n)

Scope note:

This property allows sub typing of CIDOC CRM entities –a form of specialisation – through the use of a terminological hierarchy, or thesaurus.

The CIDOC CRM is intended to focus on the high-level entities and relationships needed to describe data structures. Consequently, it does not specialise entities any further than is required for this immediate purpose. However, entities in the isA hierarchy of the CIDOC CRM may by specialised into any number of sub entities, which can be defined in the E55 Type hierarchy. E41 Appellation, for example, may be specialised into "e-mail address", "telephone number", "post office box", "URL" etc. none of which figures explicitly in the CIDOC CRM hierarchy. A comprehensive

explanation about refining CIDOC CRM concepts by E55 Type is given in the section "About Types" in the section on "Specific Modelling Constructs" of this document.

This property is a shortcut for the path from E1 CRM Entity through *P41i was classified by (classified),* E17 Type Assignment, *P42 assigned (was assigned by)* to E55 Type.

Full path:

E1 CRM Entity. P41i was classified by (classified): E17 Type Assignment: P42 assigned to (was assigned by): E55 Type

Examples:

o "enquiries@cidoc-crm.org" (E41) *has type* e-mail address (E55). (fictitious)

In first-order logic:

$P2(x,y) \Rightarrow E1(x)$
$P2(x,y) \Rightarrow E55(y)$
$P2(x,y) \Leftarrow (\exists z) [E17(z)] \wedge P41i(x,z) \wedge P42(z,y)]$

P9 consists of (forms part of)

Domain:

E4 Period

Range:

E4 Period

Subproperty of:

E92 Spacetime Volume. P10i contains (falls within): E92 Spacetime Volume

Quantification:

many to many (0,n:0,n)

Scope note:

This property associates an instance of E4 Period with another instance of E4 Period that is defined by a subset of the phenomena that define the former. Therefore, the spacetime volume of the latter must fall within the spacetime volume of the former.

This property is transitive and asymmetric.

Examples:

o Cretan Bronze Age (E4) *consists of* Middle Minoan (E4). (Hood, 1971)

In first-order logic:

$P9(x,y) \Rightarrow E4(x)$
$P9(x,y) \Rightarrow E4(y)$

$$P9(x,y) \Rightarrow P10(y,x)$$
$$[P9(x,y) \wedge P9(y,z)] \Rightarrow P9(x,z)$$
$$P9(x,y) \Rightarrow \neg P9(y,x)$$

P16 used specific object (was used for)

Domain:

E7 Activity

Range:

E70 Thing

Subproperty of:

E5 Event. P12 occurred in the presence of (was present at): E77 Persistent Item

E7 Activity. P15 was influenced by (influenced): E1 CRM Entity

Superproperty of:

E7 Activity. P33 used specific technique (was used by): E29 Design or Procedure

E15 Identifier Assignment. P142 used constituent (was used in): E90 Symbolic Object

E79 Part Addition. P111 added (was added by): E18 Physical Thing

Quantification:

many to many (0,n:0,n)

Scope note:

This property describes the use of material or immaterial things in a way essential to the performance or the outcome of an instance of E7 Activity.

This property typically applies to tools, instruments, moulds, raw materials and items embedded in a product. It implies that the presence of the object in question was a necessary condition for the action. For example, the activity of writing this text required the use of a computer. An immaterial thing can be used if at least one of its carriers is present. For example, the software tools on a computer.

Another example is the use of a particular name by a particular group of people over some span to identify a thing, such as a settlement. In this case, the physical carriers of this name are at least the people understanding its use.

Properties:

P16.1 mode of use: E55 Type

Scope note:

This property specifies the uses a thing has been subject to, in the context of it being employed in a particular activity.

Examples:

- o The writing of the scope note of the CIDOC CRM property "P16 used specific object" contained in the CIDOC CRM version 4.1 (E7) used specific object Nicholas Crofts' computer (E22) mode of use Typing Tool; Storage Medium (E55). [the original scope note was later extended in the CIDOC CRM version 4.3]
- o The people of Iraq calling the place identified by TGN '7017998' (E7) used specific object "Quyunjig" (E41) mode of use current; vernacular (E55).

In first-order logic:

P16(x,y) ⇒ E7(x)
P16(x,y) ⇒ E70(y)
P16(x,y) ⇒ P12(x,y)
P16(x,y) ⇒ P15(x,y)
P16(x,y,z) ⇒ [P16(x,y) ∧ E55(z)]

P17 was motivated by (motivated)

Domain:

E7 Activity

Range:

E1 CRM Entity

Subproperty of:

E7 Activity. P15 was influenced by (influenced): E1 CRM Entity

Quantification:

many to many (0,n:0,n)

Scope note:

This property describes an item or items that are regarded as a reason for carrying out the instance of E7 Activity.

For example, the discovery of a large hoard of treasure may call for a celebration, an order from headquarters can start a military manoeuvre.

Examples:

- · The resignation of the chief executive (E7) was motivated by the collapse of SwissAir (E68).

· The coronation of Elizabeth II (E7) was motivated by the death of George VI (E69). (Strong, 2005)

In first-order logic:

$P17(x,y) \Rightarrow E7(x)$

$P17(x,y) \Rightarrow E1(y)$

$P17(x,y) \Rightarrow P15(x,y)$

P94 has created (was created by)

Domain:

E65 Creation

Range:

E28 Conceptual Object

Subproperty of:

E63 Beginning of Existence. P92 brought into existence (was brought into existence by): E77 Persistent Item

Superproperty of:

E83 Type Creation. P135 created type (was created by): E55 Type

Quantification:

one to many, necessary, dependent (1,n:1,1)

Scope note:

This property links an instance of E65 Creation to the instance of E28 Conceptual Object created by it.

It represents the act of conceiving the intellectual content of the instance of E28 Conceptual Object. It does not represent the act of creating the first physical carrier of the instance of E28 Conceptual Object. As an example, this is the composition of a poem, not its commitment to paper.

Examples:

o The composition of "The Four Friends" by A. A. Milne (E65) has created "The Four Friends" by A. A. Milne (E33). (Milne, 2012)

In first-order logic:

$P94(x,y) \Rightarrow E65(x)$

$P94(x,y) \Rightarrow E28(y)$

$P94(x,y) \Rightarrow P92(x,y)$

P106 is composed of (forms part of)

Domain:

E90 Symbolic Object

Range:

E90 Symbolic Object

Superproperty of:

E73 Information Object. P165 incorporates (is incorporated in): E90 Symbolic Object

Quantification:

many to many (0,n:0,n)

Scope note:

This property associates an instance of E90 Symbolic Object with a part of it that is by itself an instance of E90 Symbolic Object, such as fragments of texts or clippings from an image.

This property is transitive and asymmetric.

Examples:

∙ This Scope note of property P106 (E33) is composed of 'fragments of texts' (E33).

∙ 'recognizable' (E90) is composed of 'ecognizabl' (E90).

In first-order logic:

$P106(x,y) \Rightarrow E90(x)$

$P106(x,y) \Rightarrow E90(y)$

$[P106(x,y) \wedge P106(y,z)] \Rightarrow P106(x,z)$

$P106(x,y) \neg P106(y,x)$

P129 is about (is subject of)

Domain:

E89 Propositional Object

Range:

E1 CRM Entity

Subproperty of:

E89 Propositional Object. P67 refers to (is referred to by): E1 CRM Entity

Quantification:

       many to many (0,n:0,n)

Scope note:

       This property documents that an instance of E89 Propositional Object has as subject an instance of E1 CRM Entity.

       This differs from *P67 refers to (is referred to by)*, which refers to an instance of E1 CRM Entity, in that it describes the primary subject or subjects of an instance of E89 Propositional Object.

Examples:

       o The text entitled 'Reach for the sky' (E33) is about Douglas Bader (E21). (Brickhill, 2001)

In first-order logic:

       $P129(x,y) \Rightarrow E89(x)$
       $P129(x,y) \Rightarrow E1(y)$
       $P129(x,y) \Rightarrow P67(x,y)$

P130 shows features of (features are also found on)

Domain:

       E70 Thing

Range:

       E70 Thing

Superproperty of:

       E33 Linguistic Object. P73i is translation of (has translation): E33 Linguistic Object
       E18 Physical Thing. P128 carries (is carried by): E90 Symbolic Object

Quantification:

       many to many (0,n:0,n)

Scope note:

       This property generalises the notions of "copy of" and "similar to" into a directed relationship, where the domain expresses the derivative or influenced item and the range the source or influencing item, if such a direction can be established. The property can also be used to express similarity in cases that can be stated between two objects only, without historical knowledge about its reasons. The property expresses a symmetric relationship in case no direction of influence can be

established either from evidence on the item itself or from historical knowledge. This holds in particular for siblings of a derivation process from a common source or non-causal cultural parallels, such as some weaving patterns.

The P130.1 kind of similarity property of the P130 shows features of (features are also found on) property enables the relationship between the domain and the range to be further clarified, in the sense from domain to range, if applicable. For example, it may be expressed if both items are product "of the same mould", or if two texts "contain identical paragraphs".

If the reason for similarity is a sort of derivation process, i.e., that the creator has used or had in mind the form of a particular thing during the creation or production, this process should be explicitly modelled. In these cases, P130 shows features of (features are also found on) can be regarded as a shortcut of such a process. However, the current model does not contain any path specific enough to infer this property. Specializations of the CIDOC CRM may however be more explicit, for instance describing the use of moulds etc.

This property is not transitive. This property is irreflexive.

Properties:

P130.1 kind of similarity: E55 Type

Scope note:

This property enables the relationship between two items to be further specified.

Examples:

· Mary Lamb's Cymbeline from Charles and Mary Lamb's Tales from Shakespeare (E89) shows features of William Shakespeare's Cymbeline (E89). (Carrington, 1954)
· The audio recording of Dante Alighieri's La divina commedia read by Enrico de Negri (E73) shows features of the text of Dante Alighieri's La divina commedia (E89). (Alighieri, 1956)

In first-order logic:

$P130(x,y) \Rightarrow E70(x)$
$P130(x,y) \Rightarrow E70(y)$
$P130(x,y,z) \Rightarrow [P130(x,y) \wedge E55(z)]$
$\neg P130(x,x)$

P134 continued (was continued by)

Domain:

E7 Activity

Range:

E7 Activity

Subproperty of:

E7 Activity. P15 was influenced by (influenced): E1 CRM Entity

E2 Temporal Entity. P176i starts after the start of (starts before the start of): E2 Temporal Entity

Quantification:

many to many (0,n:0,n)

Scope note:

This property associates two instances of E7 Activity, where the domain is considered as an intentional continuation of the range. A continuation of an activity may happen when the continued activity is still ongoing or after the continued activity has completely ended. The continuing activity may have started already before it decided to continue the other one. Continuation implies a coherence of intentions and outcomes of the involved activities.

This property is not transitive. This property is asymmetric.

Examples:

· The construction of the Kölner Dom (Cologne Cathedral), abandoned in the 15th century (E7), was continued by construction in the 19th century (E7). [The construction in the 19th century adapted the initial plans so as to preserve the intended appearance.] (Wolff, 1999)

In first-order logic:

P134(x,y) ⇒ E7(x)
P134(x,y) ⇒ E7(y)
P134(x,y) ⇒ P15(x,y)
P134(x,y) ⇒ P176i(x,y)
P134(x,y) ⇒ ¬P134(y,x)

P138 represents (has representation)

Domain:

E36 Visual Item

Range:

E1 CRM Entity

Subproperty of:

E89 Propositional Object. P67 refers to (is referred to by): E1 CRM Entity

Quantification:

many to many (0,n:0,n)

Scope note:

This property establishes the relationship between an instance of E36 Visual Item and the instance of E1 CRM Entity that it visually represents.

Any entity may be represented visually. This property is part of the fully developed path from E24 Physical Human-Made Thing through *P65 shows visual item (is shown by),* E36 Visual Item, *P138 represents (has representation)* to E1 CRM Entity, which is shortcut by *P62 depicts (is depicted by).*

This property is also used for the relationship between an original and a digitisation of the original by the use of techniques such as digital photography, flatbed or infrared scanning. Digitisation is here seen as a process with a mechanical, causal component rendering the spatial distribution of structural and optical properties of the original and does not necessarily include any visual similarity identifiable by human observation.

Properties:

P138.1 mode of representation: E55 Type

Scope note:

This property allows the nature of the representation of an entity to be refined

Examples:

o The digital file found at http://www.emunch.no/N/full/No-MM_N0001-01.jpg (E36) represents page 1 of Edward Munch's manuscript MM N 1, Munch-museet (E22) mode of representation Digitisation (E55).
o The 3D model VAM_A.200-1946_trace_1M.ply (E73) represents Victoria & Albert Museum's Madonna and child sculpture (visual work) A.200-1946 (E22) mode of representation 3D surface (E55).

In first-order logic:

P138(x,y) ⇒ E36(x)
P138(x,y) ⇒ E1(y)
P138(x,y,z) ⇒ [P138(x,y) ∧ E55(z)]

$$P138(x,y) \Rightarrow P67(x,y)$$

P148 has component (is component of)

Domain:

        E89 Propositional Object

Range:

        E89 Propositional Object

Quantification:

        many to many (0,n:0,n)

Scope note:

        This property associates an instance of E89 Propositional Object with a structural part of it that is by itself an instance of E89 Propositional Object.

        This property is transitive. This property is asymmetric.

Examples:

- Dante's "Divine Comedy" (E89) has component Dante's "Hell" (E89). (Alighieri, 1956)

In first-order logic:

$$P148(x,y) \Rightarrow E89(x)$$
$$P148(x,y) \Rightarrow E89(y)$$
$$[P148(x,y) \wedge P148(y,z)] \Rightarrow P148(x,z)$$
$$P148(x,y) \Rightarrow \neg P148(y,x)$$

8.3   Referred CIDOC CRMsci Classes

This section contains the complete definitions of the classes of the CIDOC CRMsci family model version 3.0 referred to by the model

S15 Observable Entity

Subclass of:

        E1 CRM Entity

Superclass of:

> S10 Material Substantial
> E5 Event

Scope note:

> This class comprises instances of E5 Event or S10 Material Substantial (i.e. items or phenomena, such as physical things, their behaviour, states and interactions or events), that can be observed by measurement or detection devices or by human sensory impression including when enhanced by tools.
>
> In order to be observable, instances of E5 Event must consist of some interaction or action of material substance. In some cases, the spatiotemporal confinement of the event itself, such as a flash, a car stopping etc. marks the limits of a documented observation of an event. In other cases, such as the situation of a car passing by a certain object, the spatiotemporal limits of the event of observing itself, as well as the direction of attention or the orientation of used instruments, may constrain the observed detail of a larger process, e.g., noticing the sight of a car passing by; a light emission, etc.
>
> Conceptual objects manifest through their carriers such as books, digital media, or even human memory. Attributes of conceptual objects, such as number of words, can be observed on their carriers. If the respective properties between carriers differ, either they carry different instances of conceptual objects or the difference can be attributed to accidental deficiencies in one of the carriers. In that sense, even immaterial objects are observable. By this model we address the fact that frequently, the actually observed carriers of conceptual objects are not explicitly identified in documentation, i.e., they are assumed to have existed but they are unknown as individuals.

Examples:

> - the domestic goose from Guangdong/1/1996 (H5N1) that was identified in 1996 in farmed geese in southern China as circulating highly pathogenic H5N1 (E20) (Wan, 2012)
> - the flight of a male Bearded Vulture observed near Loukia, Heraklion, Crete in the morning of the 24th of October 2020 (E5) [The Bearded Vulture (Gypaetus Barbatus) is a threatened species in Crete] (Claes, 2020)
> - the eruption of Krakatoa volcano at Indonesia in 1883 (E5) (Symons et al., 1888)
> - the cupid head area in the X-Ray of the painting 'Cupid complaining to Venus' (E25) (The National Gallery, London, 1963)
> - Earth's magnetic field (S15) [a magnetic field is neither S10 nor E5]

In first-order logic:

$$S15(x) \Rightarrow E1(x)$$
$$E5(x) \Rightarrow S15(x)$$

Properties:

O12 has dimension (is dimension of): E54 Dimension

S27 Observation

Subclass of:

I1 Argumentation

Superclass of:

S4 Single Observation
S19 Encounter Event
S21 Measurement
S23 Position Determination

Scope note:

This class comprises activity of gaining scientific knowledge about particular states of physical reality through empirical evidence, experiments and measurements.

We define observation in the sense of natural sciences, as a kind of human activity: at some place and within some time-span, certain physical things and their behaviour and interactions are observed by human sensory impression, and often enhanced by tools and measurement devices.

Observed situations or dimensions may pertain to properties confined to a single instance of S15 Observable Entity or pertain to constellations of multiple instances and relations between them, in particular distances between them.

The output of the internal processes of measurement devices that do not require additional human interaction are in general regarded as part of the observation and not as additional inference. Primary data from measurement devices are regarded in this model to be results of observation and can be interpreted as propositions believed to be true within the (known) tolerances and degree of reliability of the device.

Measurements and witnessing of events are special cases of observations. Observations result in a belief that certain propositions held at a time within the time-span of the observation. In this model, the degree of confidence in the observed properties is regarded to be "true" by default, but could be described differently by adding a property *P3 has note* to an instance of S4 Observation.

Examples:

- the excavation of unit XI by the Archaeological Institute of Crete in 2004
- the excavation in the NE section of the central court of the Knossos palace by the Ephorate of Antiquities of Heraklion in 1997 (Επιστημονική Επιτροπή Κνωσού, 2008)
- the observation of the density of the X-Ray image of cupid's head from the painting 'Cupid complaining to Venus' as 'high density', on the 19th of March 1963 (S4) (The National Gallery, London, 1963)
- the observation of visible light absorption of the painting 'Cupid complaining to Venus' as 'having red pigment', in 2015 (S4)
- the inspection of the interior of La Tomba dell'Aryballos sospeso, at Doganaccia di Tarquinia, in Tuscany, Italy, by Alessandro Mandolesi on the 21st of September 2013 (Mandolesi 2013)

In first-order logic:

$S27(x) \Rightarrow I1(x)$

Properties:

O35 observed entity (was observed by): S15 Observable Entity
O36 expressed the observed as (was the expression of): S28 Observable Situation

S28 Observable Situation

Subclass of:

I11 Situation

Superclass of:

S29 Observable Proposition

Scope note:

An instance of S28 Observable Situation can be perceived as a set of formal propositions deriving from an observation event on a constellation, an interaction or a dynamic behaviour of instances of S15 Observable Entity, or sections of these instances within a particular time-span and spatial extent that lie in the past. The observation event in question either relies on human senses, or it has been enhanced or mediated by technical instruments.

The observer may be directly involved themselves, or they may be receiving signals from each observation. The focus of the observer determines the model they overlay on the observed reality, in order to describe it in terms of distinct properties and value ranges of parameters. The latter selection and projection from reality constitutes the content of a particular instance of S28 Observable Situation. Multiple observers may

select different models, details and value systems to the same spatiotemporal area (i.e., views they pay attention to). Consequently, the observed situations may differ, but should, in principle, be comparable to a common reality in their overlaps.

Examples:

- the proposition set with content:

  {The burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object) *is composed of* the spear found in La Tomba dell' Aryballos sospeso (E22 Human-Made Object)

  The skeleton in La Tomba dell'Aryballos sospeso on the left bench (E20 Biological Object) forms part of the burial arrangement on La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object).}

  (Mandolesi, 2013)

- the proposition set with content:

  {The content of the La Tomba dell'Aryballos sospeso at the time of its opening (E24 Physical Human-Made Thing) *is composed of* the burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object).

  The burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object) *is composed of* the spear found in La Tomba dell'Aryballos sospeso (E22 Human-Made Object).

  The skeleton in La Tomba dell'Aryballos sospeso on the left bench (E20 Biological Object) *forms part of* the burial arrangement in La Tomba dell'Aryballos sospeso on the left bench (E22 Human-Made Object).

  The skeleton in La Tomba dell'Aryballos sospeso on the right bench (E20 Biological Object) *forms part of* the content of the La Tomba dell'Aryballos sospeso at the time of its opening (E24 Physical Human-Made Thing).

  The content of the La Tomba dell'Aryballos sospeso at the time of its opening (E24 Physical Human-Made Thing) *has condition* the condition of the content of the La Tomba dell'Aryballos sospeso from its sealing to its opening (E3 Condition State).

  The condition of the content of the La Tomba dell'Aryballos sospeso from its sealing to its opening (E3 Condition State) *has type* 'intact' (E55 Type).

  (Mandolesi 2013)

[The abovementioned examples form part of a scientific knowledge revision, where the original belief was formed based on a simple inference, and following a thorough scientific analysis, underwent revision.

The skeleton found on the left bench of La Tomba dell'Aryballos sospeso, at Doganaccia di Tarquinia, in Tuscany, Italy, by Prof. Alessandro Mandolesi on the 21st September 2013, was initially estimated to be the remains of a male person, due to a

spear found lying next to it. In fact, the initial press release mentioned there being a skeleton of a male person in the tomb. Soon after, osteological analysis carried out by Mandolesi's team, revealed that the skeleton had belonged to a female person, a piece of information included in all scientific publications that followed the osteological analysis.

We refer to this skeleton in the examples found throughout the text as "The skeleton on the left bench in La Tomba dell'Aryballos sospeso", and to the burial arrangement as "The burial arrangement on the left bench in La Tomba dell'Aryballos sospeso", respectively.]

- a triple-braided clasp strap being detached at the survey of Sinai MS GREEK 418 (Honey and Pickwoad, 2010).

In first-order logic:

$S28(x) \Rightarrow I11(x)$

$S28(x) \Rightarrow (\exists y) [S15(y) \wedge J28(x,y)]$

Properties:

O40 refers to observable entity (is referred to in): S15 Observable Entity

8.4 Referred CIDOC CRMdig Classes

This section contains the complete definitions of the classes of the CIDOC CRMdig family model version 4.0 referred to by the model.

D1 Digital Object

Subclass of:

E73 Information Object

Superclass of:

D9 Data Object

D14 Software

D35 Area

Scope note:

This class comprises identifiable immaterial items that can be represented as sets of bit sequences, such as data sets, e-texts, images, audio or video items, software, etc., and are documented as single units.

Any aggregation of instances of D1 Digital Object into a whole treated as single unit is also regarded as an instance of D1 Digital Object.

This means that for instance, the content of a DVD, an XML file on it, and an element of this file, are regarded as distinct instances of D1 Digital Object, mutually related by the P106 is composed of (forms part of) property.

A D1 Digital Object does not depend on a specific physical carrier, and it can exist on one or more carriers simultaneously.

In First Order Logic:

$D1(x) \Rightarrow E73(x)$

D2 Digitization Process

Subclass of:

D11 Digital Measurement Event

Scope note:

This class comprises events that result in the creation of instances of D9 Data Object that represent the appearance and/or form of an instance of E18 Physical Thing such as paper documents, statues, buildings, paintings, etc.

A particular case is the analogue-to-digital conversion of audiovisual material.

This class represents the transition from a material thing to an immaterial representation of it.

The characteristic subsequent processing steps on digital objects are regarded as instances of D3 Formal Derivation.

In First Order Logic:

$D2(x) \Rightarrow D11(x)$

Properties:

L1 digitized (was digitized by): E18 Physical Thing

L60 documents: E1 CRM Entity

D9 Data Object

Subclass of:

    D1 Digital Object

    E31 Document

Scope note:

    This class comprises instances of D1 Digital Object that are the result of measurements or other observations and / or their algorithmic evaluation in the form of structured data, such as encoded formal propositions, CSV files ("comma separated values") or equivalent representations.

    If an instance of D1 Digital Object contains the value set of an instance of E54 Dimension, such as the primary data from an instance of S21 Measurement, this association can be documented with the property *L61 contains value set of (has value set representation).*

In First Order Logic:

    $D9(x) \Rightarrow D1(x)$

    $D9(x) \Rightarrow E54(x)$

Properties:

    L61 contains value set of (has value set representation): E54 Dimension

8.5 Referred CIDOC CRMdig Properties

This section contains the complete definitions of the properties of the CIDOC CRMdig Model version 4.0 referred to.

L1 digitized (was digitized by)

Domain:

D2 Digitization Process

Range:

E18 Physical Thing

Subproperty of:

E16 Measurement: P39 measured (was measured by): E18 Physical Thing

Scope note:

This property associates an instance of D2 Digitization Process with an instance of E18 Physical Thing which is a material thing.

In First Order Logic:

L1(x,y) ⇒ D2(x)

L1(x,y) ⇒ E18(y)

L1(x,y) ⇒ P39(x,y)

L20 has created (was created by)

Domain:

D11 Digital Measurement Event

Range:

D9 Data Object

Subproperty of:

D7 Digital Machine Event:L11 had output (was output of):D1 Digital Object

Scope note:

This property identifies a Data Object that came into existence as a result of a D11 Digital Measurement Event

8.6 Referred CIDOC CRMinf Classes

This section contains the complete definitions of the classes of the CIDOC CRMinf family model version 1.2 referred to by the model.

I4 Proposition Set

Subclass of:

E89 Propositional Object

Superclass of:

I10 Provenance Statement
I11 Situation
I17 One-Proposition Set

Scope note:

This class comprises sets of unambiguous propositions that are, or could, in principle, be, encoded in a knowledge representation language. These propositions should be factual, i.e., each proposition should pertain to at least one particular item, in contrast to universals, such as instances of E55 Type. The identity of an instance of I4 Proposition Set is given by the total of its content, regardless of equivalent encodings.

An instance of I4 Proposition Set should be regarded per se to be neutral to its relationship to reality. The relationship to reality is determined by the link using the proposition set:

If an instance of I2 Belief refers to an instance of I4 Proposition Set, the belief value "TRUE" means that the proposition sets are believed to correspond to reality, assuming that the propositions can be related to reality –i.e., are about real-world items, in contrast to mathematical statements, for example. A belief value "FALSE" means that at least one of the propositions in the set is regarded as not corresponding to reality. Belief values expressing possibility or probability will mean "possibly real", given that the propositions can be related to reality.

Some properties associating an activity with an instance of I4 Proposition Set may imply the belief of the Actor carrying out the activity that the propositions are true. This should be expressed in the respective scope notes.

In a Knowledge Base implementation, an instance of I4 Proposition Set may be represented by the URI of a Named Graph, but only if the propositions are encoded in the data model of the Knowledge Base and held to be true by the maintainers of the Knowledge Base, because they become part of the stated knowledge. In this

case, the platform-internal relation between the URI and its content, is regarded as equivalent to the property J25 is encoded by.

Proposition Sets held to be possibly true by the maintainers of a Knowledge Base may also be introduced as Named Graphs, if the operation of the Knowledge Base foresees filtering by provenance and likelihood. In this case, Named Graphs are particularly effective.

Examples:

- the proposition set with content:

  {Nero in July 19, 64 AD (E93 Presence)

      P164 is temporally specified by: July 19, 64 AD (E52 Timespan)

      P195 was a presence of: Nero Claudius Caesar Drusus Germanicus (E21 Person)

      P167 was within Antium in 64AD, Italy (E53 Place)

      P133 is spatiotemporally separated from: The Great Fire of Rome (E5 Event)

          P1 is identified by: incendium magnum Romae (E41 Appellation)

          P4 has timespan: July 19-27, 64 AD (E52 Timespan)

          P7 took place at: Rome in 64AD, Italy (E53 Place)

       } (Bologna 2021)

  [The Proposition Set above represents Francesca Bologna's adopted belief, according to which Publius Cornelius Tacitus meant that "Nero was at Antium when the Great Fire broke out and did not return to Rome until the fire approached his house"]

- the proposition set with content:

  {Nero July 19, 64 AD (E93 Presence)

      P164 is temporally specified by: July 19, 64 AD (E52 Timespan)

      P195 was a presence of: Nero Claudius Caesar Drusus Germanicus (E21 Person)

      P167 was within Rome in 64AD, Italy (E53 Place)

          P10 falls within (contains): Nero Singing (E7 Activity)

              P2 has type: Singing (E55 Type)

              P14 carried out by: Nero Claudius Caesar Drusus Germanicus (E21)

              P4 has timespan: July 19, 64 AD (E52 Timespan)

              P7 took place at: Rome in 64AD, Italy (E53 Place)

          P132 spatiotemporally overlaps with: The Great Fire of Rome (E5 Event)

P1 is identified by: incendium magnum Romae (E41 Appellation)

P4 has timespan: July 19-27, 64 AD (E52 Timespan)

P7 took place at: Rome in 64AD, Italy (E53 Place)

} (Bologna 2021)

[The Proposition Set above represents Francesca Bologna's intended meaning belief, according to which Gaius Suetonius Tranquillus assumed that Nero was singing in Rome while it was burning from July 19 in 64 AD.]

In First Order Logic:

$$I4(x) \Rightarrow E89(x)$$

Properties:

J25 is encoded by: E62 String

J26 has unambiguous description (describes the formal meaning of): E73 Information Object

J28 contains entity reference (is contained in): E1 CRM Entity

J29 contains property type (is property type in): E55 Type

I5 Inference Making

Subclass of:

I1 Argumentation

Superclass of:

Scope note:

This class comprises the action of making honest propositions and statements about particular states of affairs in reality or possible realities, or categorical descriptions of reality by using inferences from other statements based on hypotheses and any form of formal or informal logic. It includes evaluations, calculations, and interpretations, based on mathematical formulations and propositions.

It is characterized by the use of an existing I2 Belief as the premise that, taken together with a set of I3 Inference Logic, draws a further I2 Belief as a conclusion.

Documenting instances of I5 Inference making primarily enables tracing the dependency of knowledge from conclusion to premise through subsequent inferences possibly back to primary evidence, so that the range of influence of

knowledge revision at any intermediate stage of complex inference chains on current convictions can be narrowed down by query. The explicit reference to the applied inference logic further allows scholars and scientists to assess if they can or would follow the documented argument. The class is not intended to promote the use of computationally decidable systems of logic as replacements of scholarly justifications of arguments, even though it allows for documenting the use of decidable logic, if that was deemed adequate for the problem at hand. Principles of scholarly justifications of arguments are also regarded as kinds of inference logic.

Examples:

- the gender classification of the skeleton on the left bench in La Tomba dell'Aryballos sospeso (E17, I5), provided to the press by Alessandro Mandolesi on the 21st September 2013 (Squires, 2013)
- Francesca Bologna concluding that the story, according to which, Nero took in the view of the burning city of Rome from the imperial residence while playing the lyre and singing about the fall of Troy, forms a tale devised by Suetonius and Cassius Dio (Bologna, 2021).

In First Order Logic:

$$I5(x) \Rightarrow I1(x)$$

Properties:

J1 used as premise (was a premise for): I2 Belief
J3 applies (was applied by): I3 Inference Logic

8.7 Referred CIDOC CRMinf Properties

This section contains the complete definitions of the properties of the CIDOC CRMinf Model version 1.2 referred to.

O36 expressed the observed as (was the expression of)

Domain:

S27 Observation

Range:

S28 Observable Situation

Subproperty of:

Superproperty of:

>S4 Single Observation. O37 observed proposition (observed by): S29 Observable Proposition

Quantification:

>many to one, necessary (1,1:0,n)

Scope note:

>This property associates an instance of Observation with an instance of S28 Observable Situation that the actors carrying out the observation used to express the observed phenomena of their interests. The alleged time-span of the observed situation must be equal to or within the overall time-span of the domain instance used for this property. A narrower time-span of validity for the observed situation can be documented via the property S28 Observable Situation. *J24 held at least for (is at least validity of)*: E52 Time-Span.

>This property is a strong shortcut for the path from S27 Observation through *J2 concluded that (was concluded by)*, I2 Belief, *J4 that (is subject of)*, S28 Observable Situation, *J5 holds to be*, to I6 Belief Value (= "True").

Full path:

>S27 Observation. *J2 concluded that (was concluded by)*: I2 Belief. *J4 that (is subject of)*: S28 Observable Situation. *J5 holds to be*: I6 Belief Value (= "True")

Examples:

- The observation between April, 25 and May, 3 1971 at the slope of the coastal region of Panagopoula (S27), *expressed the observed as* the rotational landslide on the same site (S15). (Tavoularis et al., 2017)
- The survey of Sinai MS GREEK 418 (S4) *expressed the observed as* a detached triple-braided clasp strap (S15). (Honey and Pickwood, 2010)

In first-order logic:

>O36(x,y) $\Rightarrow$ S27(x)
>O36(x,y) $\Rightarrow$ S28(y)
>O36(x,y) $\Leftrightarrow$ S27(x) $\wedge$ S28(y) $\wedge$ ($\exists$u) [I2(u) $\wedge$ J2(x,u) $\wedge$ J4(u,y) $\wedge$ J5(u,'TRUE')]

8.8 Referred Parthenos Classes

This section contains the complete definitions of the classes of the Parthenos model version 3.1 referred to by the model.

PE19 Persistent Digital Object

Subclass of

> D1 Digital Object

Superclass of

> PE21 Persistent Software
>
> PE22 Persistent Dataset

Scope Note

> This class comprises instances of D1 digital object which are the result of a distinct creation moment in which the whole of the content of the digital object as a propositional set was established and encoded at a bit level, whether this creation moment is known or not.
>
> Persistent digital objects are thus identified by their content, bit level encoding and the moment of production as a whole unit of information.
>
> An instance of persistent digital object continues to exist so long as one copy of it remains on one carrier which has been maintained without change to its internal content, thus propagating the original condition of the instance.

Examples

> Version 5.2 of Microsoft DOS
>
> Backup file of the shared drive at FORTH
>
> Submitted copy of deliverable 5.1 in word format

Properties:

> PP16 has persistent digital object part: PE19 Persistent Digital Object

PE20 Volatile Digital Object

Subclass of

> PE32 Curated Thing
>
> D1 Digital Object

Superclass of

> PE23 Volatile Software
>
> PE24 Volatile Dataset

Scope Note

> This class comprises instances of digital objects whose content is subject to continuous change without notice or necessary archiving of intermediate state but which can be considered as one with regards to its provenance in some curation plan that determines its information, goal and subject coverage.

At any one point, an instance of PE20 Volatile Digital Object can be identified by an official snapshot of the actual data stream, an instance of PE19 Persistent Digital Object, taken by the responsible curating authority which has as ancestors any previous snapshots taken of the data stream. The curator assigns a persistent identifier to the official snapshot and is the only individual who can identify the true representative snapshot.

Reference to the content of an instance of PE20 Volatile Digital Object is down by way of the official snapshot.

Examples

The catalogue of iTunes Store music offerings

The Archive of Archaeological Data Service UK Archaeology Data Service: Archives, n.d.)

WordNet (Gratta, et al. 2014), (IIT - CNR - Istituto di Informatica e Telematica, n.d.)

TwitterBuonaScuola Corpus (Gratta, et al. 2014), (IIT - CNR - Istituto di Informatica e Telematica, n.d.)

Properties:

PP17 has snapshot: PE19 Persistent Digital Object

PP18 has digital object part: D1 Digital object

8.9 Referred Parthenos Properties

This section contains the complete definitions of the properties of the Parthenos Model version 3.1 referred to.

PP17 has snapshot (is snapshot of)

Domain

PE20 Volatile Digital Object

Range

P19 Persistent Digital Object

Subrelation of

P130 shows features of (features are also found on)

Superrelation of

PP22 has release (is release of)

PP24 has dataset snapshot (is dataset snapshot of)

Scope

This property associates an instance of PE20 Volatile Digital Object with an instances of PE19 Persistent Object which at any one point stands as an official version of the overall data stream.

Examples

1.0 Parthenos.doc (PE19) is snapshot of Parthenos deliverable doc (PE20), before its 1st release.

PP18 has digital object part (is digital object part of)

Domain

PE20 Volatile Digital Object

Range

D1 Digital Object

Subrelation of

P106 is composed of (forms part of)

Superrelation of

PP21 has software part (is software part of)

PP23 has dataset part (is dataset part of)

Scope

This property associates an instance of PE20 Volatile Digital Object with a structural part of that instance. This structural part may be another instance of D1 Digital object, be it also a PE20 Volatile Digital Object or in fact be an instance of PE19 Persistent Object.

Examples

8.10   Referred Narrative Ontology Classes

This section contains the definitions of the classes and properties of the **Narrative Ontology**

The complete definition of the The NOnt ontology is described here: https://dlnarratives.eu/ontology/

Narration

Subclass of: F14 Individual Work

Superclass of:

Scope note:

This class represents the narration of a narrative, i.e. an individual work that tells the events of the narrative through some form of media (text, video, audio, etc.).

Examples:

Properties:

Narrative

Subclass of:

E73 Information Object

Superclass of:

biography

Scope note:

This class represents a narrative.

Examples:

Properties:
has text: E90 Symbolic Object

Referred Narrative Ontology Properties

has text

Domain:

Narrative

Range:

E90 Symbolic Objectc

Scope note:

This property relates a narrative to the text that expresses it.

part of narrative

Domain:

E5 Event

Range:

Narrative

Scope note:

This property relates an event to the narrative that contains it.

9 Disclaimer

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