ECHOES
European Cloud for Heritage Open Science

Heritage Digital Twins Ontology

First report

Version 0.1 published by June 2025

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Executive Summary

This report consists of the first draft of the Heritage Digital Twin ontology (HDTO), published in June 2025, 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 largely based on earlier work presented here https://arxiv.org/pdf/2302.07138; the current model description is proposed as an improvement and clarification of this earlier version. The description includes comments and proposes changes on the basic entities and relationships.

The proposal includes refinement on the scope notes, reviews on the existing properties (changes in the domain or range), addition of new properties and addition of IsA relationships). The proposed modifications are necessary to be compliant with the respective ontologies that the model extends and harmonise (CIDOC CRM version 7.3, CRMsci, CRMdig, CRMinf, CRMba, etc.), reduce complexity, make possible effective integration and increase extensibility. Additionally, it considers the proposed revision of the current version of CRMinf and CRMsci, which includes the simplification of the documentation of premises and conclusions, the extension to a multi proposition observation (unifying reification and named graphs) and measurements of dimensions relating multiple entities.

The proposed changes provide a general pattern how to relate references to reification patterns to sets of propositions. It should be noted that the semantics of referring to a set of propositions is more expressive than referring to the contained propositions one by one. Additionally, proposals on better modelling practices are included, such as the finding of the minimal class to describe a common generalisation and the creation of sub properties, which help to make the model robust and efficient and maximise the integration procedure.

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

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1. Introduction

1.1 Purpose and Scope of the Document

The purpose of the document is to present a first draft of 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.

1.2 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).

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2. Notes on Basic Concepts of the Ontology

The most general notion of the model is that of **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, 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 attributes.

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” may be defined by an authority that acts on behalf or in favor of the contextual society within a specific contextual period (such as UNESCO European policies or EUROPEANNA consortium definition).

A project documenting entities 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 also decide to include things or traditions regarded as particular heritage by informal or traditional communities. 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 will allow for documenting all what should be, regardless of whether national or other authorities summarily regard some categories of items as heritage. *Not* documenting an item as instance of HC1 in a knowledge base does *not* constitute a statement about not being heritage in some sense.

HC1 is the focal concept of the ontology and serves as an entry point for linking to HC2.

«*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 aspects of the same Heritage Entity are recorded as Tangible Aspect and Intangible Aspect. While all Heritage Entities are*

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related to an intangible aspect, some Heritage Entities may not have the tangible one and only exist as intangible. »

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 Aspects would differ from the entity associated with the Digital Twin.

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.

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3. Class Declaration

HC1 Heritage Entity

Subclass of: crm: E70 Thing
Superclass of: HC3 Tangible Aspect
HC4 Intangible Aspect

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, part of the Knossos WH archaeological site
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: crm:E89 Propositional Object
Superclass of:

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Scope Note:

The class comprises sets of formal propositions more or less directly 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 contained 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.
The identity of an instance of HC2 Heritage Digital Twin is determined by its content (set of statements) and the creating authority group. In the context of the defining project or authority, every instance of HC1 Heritage Entity should linked to one instance of HC2 Heritage Digital Twin being 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 declarations of instances of HC2, created by different projects, that may overlap or include each other. 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.
Since instances of HC2 Heritage Digital Twin are **volatile objects** in the sense of the **Parthenos Entity Model[1],** 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.

[1] **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.

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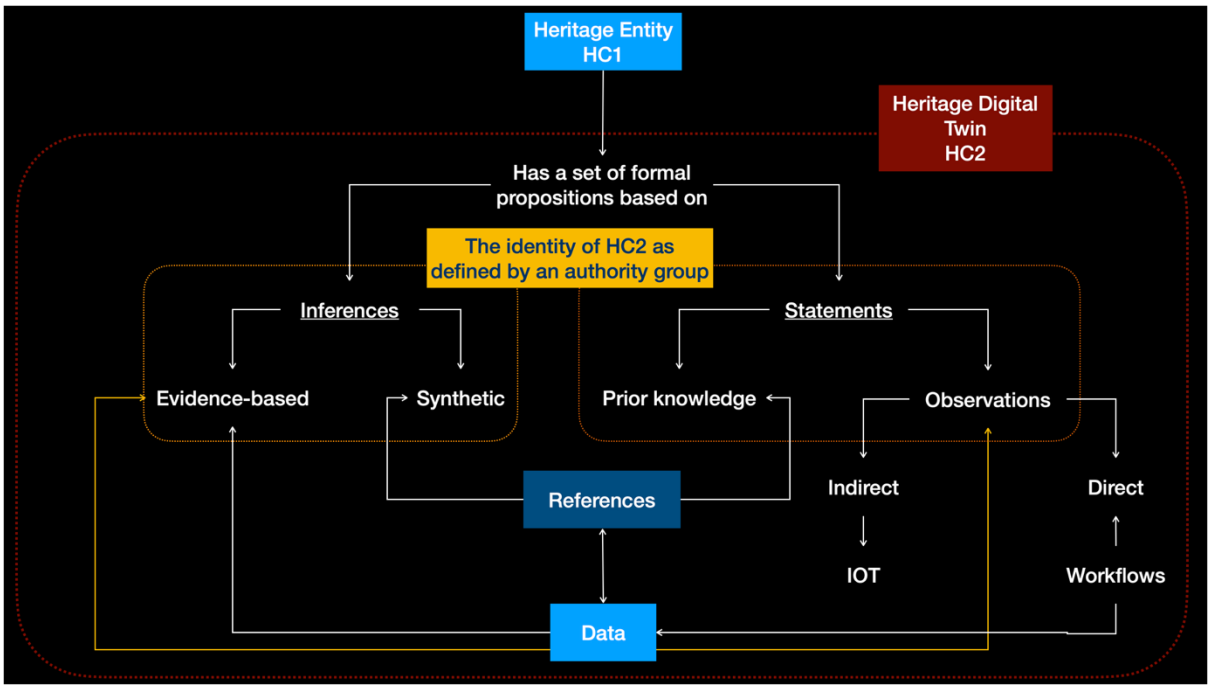

Figure 1: HC2 Heritage Digital Twin

Examples:

the HDT of the Neptune Fountain in Bologna
the HDT of Knossos Palace

Properties:

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

HC3 Tangible Aspect

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 aspect, which is specified through the HP5 has intangible aspect property.

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Examples:

the Neptune Fountain in Bologna (Italy)
the Pisa Leaning Tower, a UNESCO World Heritage (WH) Site
the Nike of Samothrace of the Louvre Museum in Paris (France)

Properties:

HP5 has intangible aspect (is intangible aspect of): HC4 Intangible Aspect
HP7 is manifestation of (is manifested by): HC4 Intangible Aspect
crmdig:L1 was digitized by (digitized): crmdig:D2 Digitization Process

HC4 Intangible Aspect

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 Aspect is identified by a society or by evidence or other kind of manifestations. The identity of an Intangible Aspect 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

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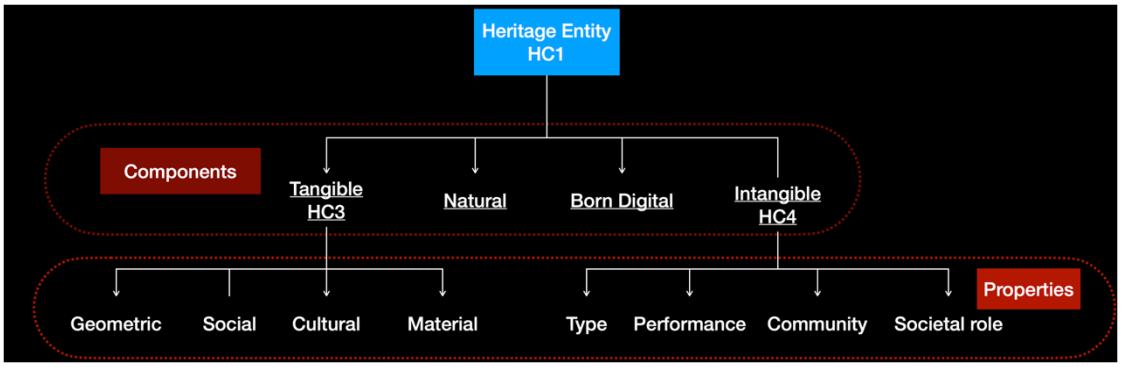

Figure 2: HC4 Intangible aspect

HC5 Digital Representation

Subclass of: crmdig:D1 Digital Object
Superclass of: HC6 Digital Document
HC7 Digital Visual Object
HC8 3D Model

Scope Note:

This class comprises the digital virtual representations of an HC1 Heritage Entity such as e-texts, images, audio or video items, 3D models, etc., that are documented as single units.

Examples:

The digital version of Vasari's "Vite"
the video https://www.youtube.com/watch?v=P1Uv4Zf5xKk

Properties:

HP22 represents (has digital representation): HC1 Heritage Entity

HC6 Digital Document

Subclass of: HC5 Digital Representation
Superclass of:

Scope Note:

This class comprises pieces or collections of digital, non-visual documents, either born-digital or digitised from physical, real-world ones, typically containing textual or numerical information regarding an HC1 Heritage Entity and intended to become part of the related HC2 Heritage Digital Twin. Documentation of this kind may include scientific data, research results and interpretation, as well as historical and cultural information, including textual

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descriptions related to the nature, conditions, positioning and to the whole set of events in which the cultural entity has been involved and the actors who have participated in them.

Examples:

Properties:

HP11 documents (is documented in): HC1 Heritage Entity

HC7 Digital Visual 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_c ustom_att_2_simple_viewer).

Properties:

HP9 is visual representation of (has visual representation): HC1 Heritage Entity

HC8 3D Model

Subclass of: HC5 Digital Representation
Superclass of:

Scope Note:

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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.

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, C14 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 HC9 Study may directly be related to the execution of a particular scholarly workflow aiming at systematically planning, finding or initiating studies

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and collecting their results until they cover all disciplinary aspects intended by a respective project.
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)"

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
HP26 studied specifically (was studied by): crm: E1 CRM Entity

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

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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 KR - Heritage Digital Twin Documentation

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 all relevant scientific and scholarly disciplines and its provenance. Such knowledge is typically 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 KR Heritage Documentation 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:

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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

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. As work continues, the instance will

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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 in 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:

3.1 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 instance of the Heritage Digital Twin of the composite Heritage Entity.

Examples:

- The Deryneia icon, Cyprus (HC1) *has digital twin (HP1)* the deryneia icon 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:

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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 the UNESCO WHS The monastery of St. John Lmabadistis is a *HP3 digital twin component of* the HP3 digital twin component of the UNESCO "Painted Troodos Churches in Cyprus".

HP4 narrates (is narrated through)

Domain: nont:Narration
Range: nont:Narrative
Subproperty of:
Superproperty of:
Quantification:
Scope note: This property links an instance of nont:Narration with an instance of a nont:Narrative which has this narration. It is similar to the nont:hasNarration property, but is not a subproperty of crm:P148 has component.

Examples:

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

HP5 has intangible aspect (is intangible aspect of)

Domain: HC3 Tangible Aspect
Range: HC4 Intangible Aspect
Subproperty of:
Superproperty of:
Quantification:

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

Examples:

- The “Theotokos of Vladimir” (HC3) icon *HP5 has intangible aspect* the secular veneration that is addressed to it (HC4).

HP6 has manifestation event (event is manifestation of)

Domain: HC4 Intangible Aspect
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 Aspect 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 Aspect
Range: HC4 Intangible Aspect
Subproperty of:
Superproperty of:
Quantification:

Scope note: This property associates instances of HC3 Tangible Aspect with the HC4 Intangible Aspect 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:Narration
Range: crm:E31 Document
Subproperty of:
Superproperty of:
Quantification:

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Scope note: This property associates an instance of nont:Narration with instances of E31 Document used to implement 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 Visual Object
Range: HC1 Heritage Entity
Subproperty of:
HC5 Digital Representation: HP22 represents (has digital representation): HC1 Heritage Entity
Superproperty of:
Quantification:

Scope note: This property associates an instance of HC1 Heritage Entity with instances of HC7 Digital Visual 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 (HC1) *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:
Superproperty of:
Quantification:

Scope note: This property is intended to identify the specific events (E5) to which a nont:Narrative relates.

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)

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HP11 documents (is documented in)

Domain: HC6 Digital Document
Range: HC1 Heritage Entity
Subproperty of:
HC5 Digital Representation: HP22 represents (has digital representation): HC1 Heritage Entity
Superproperty of:
Quantification:

Scope note: This property describes the HC1 Heritage Entity documented by instances of HC6 Digital Document.

Examples:

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:

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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.

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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 KR Heritage Documentation
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 Heritage Documentation with an instance of a Heritage Entity that refers to.

Examples:

The ECHOES Project team CNRS Documentation (HC11) *has documented* (HP18) the St. John Lambadistis monastery in Cyprus (HC1)

HP19 has composed (was composed by)

Domain: HC11 KR Heritage Documentation
Range: HC2 Digital Twin
Subproperty of: crm:P94 has created (was created by): crm:E28 Conceptual Object

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Superproperty of:
Quantification:
many to one, necessary (1,1:0,n)

Scope note: This property links an instance of HC11 KR Heritage Documentation with an instance of HC2 Digital Twin it has composed or complemented.
Examples:
The ECHOES Project team CyI Documentation (HC11) *has composed (HP19)* the HDT of the Pafos Gate in Nicosia (HC2)

HP20 was carried out under (had contribution)

Domain: HC11 KR Heritage Documentation
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 KR Heritage Documentation with an instance of HC13 Project on behalf of which the documentation was carried out.
This property is a shortcut of the more fully developed path from HC11 KR Heritage Documentation through *HP34i was completed by (completed)*, HC14 Digital Twin Supervision, *HP28 was carried out under (had task)* to HC13 Project.
Examples:
The ECHOES Project team CNRS Documentation (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): HC1 Heritage 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)

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Domain: HC5 Digital Representation
Range: HC1 Heritage Entity
Subproperty of: crm: E36 Visual Item. P138 represents (has representation): E1 CRM Entity
Superproperty of:
HC7 Digital Visual Object: HP9 is visual representation of (has visual representation): HC1 Heritage Entity
HC6 Digital Document**:** HP11 documents (is documented in): HC1 Heritage 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 HC1 Heritage 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 Aspect and HC4 Intangible Aspect) 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)

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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).

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HP27 used content of (content was used by)

Domain: HC11 KR Heritage Documentation
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 KR Heritage Documentation 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).

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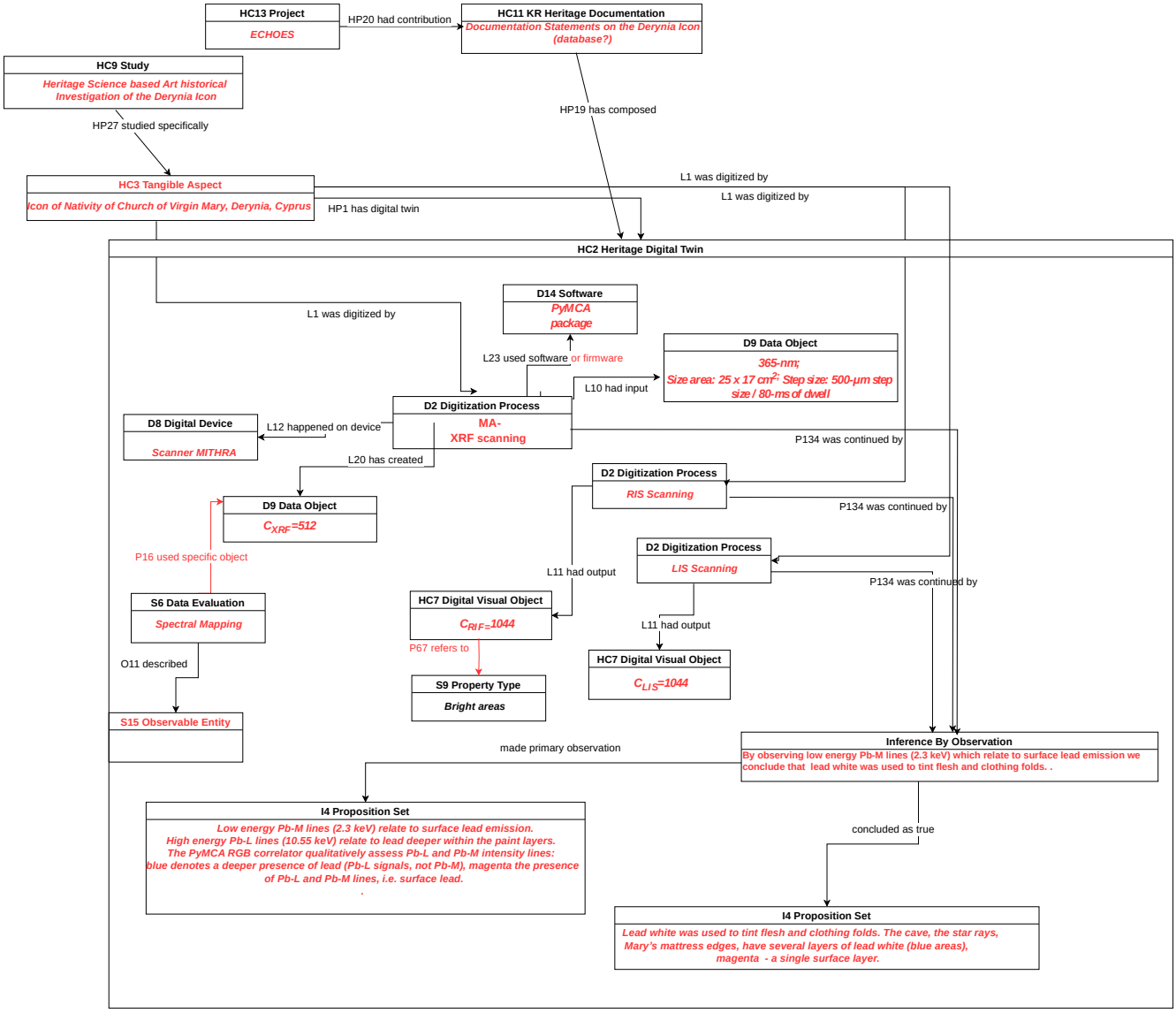

Figure 3: Diagram representation of the HDTO of the Deryneia icon, Cyprus.

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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.

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.

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:

- Bronze Age (E4) (Childe, 1963)

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

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,

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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:

- the birth of Cleopatra (E67) (Pomeroy, 1984)
- the destruction of Herculaneum by volcanic eruption in 79 AD (E6) (Camardo, 2013)
- World War II (E7) (Barber, 1994)
- the Battle of Stalingrad (E7) (Hoyt, 1993)
- the Yalta Conference (E7) (Harbutt, 2010)
- my birthday celebration 28-6-1995 (E7)
- the falling of a tile from my roof last Sunday (fictitious)
- the CIDOC conference 2003 (E7)

In first-order logic:

$E5(x) \Rightarrow E4(x)$

Properties:

P11 had participant (participated in): E39 Actor
P12 occurred in the presence of (was present at): E77 Persistent Item

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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:

- the Battle of Stalingrad (Hoyt, 1993)
- the Yalta Conference (Harbutt, 2010)
- my birthday celebration 28-6-1995
- the writing of “Faust” by Goethe (E65) (Williams, 2020)
- the formation of the Bauhaus 1919 (E66) (Droste, 2006)
- calling the place identified by TGN ‘7017998’ ‘Quyunjig’ by the people of Iraq
- Kira Weber working in glass art from 1984 to 1993 (Weber, 2012)
- Kira Weber working in oil and pastel painting from 1993 up to present (Weber, 2012)

In first-order logic:

$E7(x) \Rightarrow E5(x)$

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)

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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

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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:

- the examination of MS Sinai Greek 418 by Nicholas Pickwoad in November 2003 (Honey & Pickwoad, 2010)
- 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

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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:

- the Cullinan Diamond (E19) (Scarratt and Shor, 2006)
- the cave “Ideon Andron” in Crete (E26) (Smith, 1844-49)
- 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

E31 Document

Subclass of:

E73 Information Object

Superclass of:

E32 Authority Document

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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:

- the Encyclopaedia Britannica (E32) (Kogan, 1958)
- the image content of the photo of the Allied Leaders at Yalta published by UPI, 1945 (E36)
- 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

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:

- the framing of the U.S. Constitution (Farrand, 1913)
- 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:

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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:

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

In first-order logic:

E70(x) ⇒ 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)

E71 Human-Made Thing

Subclass of:

E70 Thing

Superclass of:

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E24 Physical Human-Made Thing
E28 Conceptual Object

Scope note:

This class comprises discrete, identifiable human-made items that are documented as single units.

These items are either intellectual products or human-made physical things, and are characterized by relative stability. They may for instance have a solid physical form, an electronic encoding, or they may be logical concepts or structures.

Examples:

- Beethoven's 5th Symphony (E73) (Lockwood, 2015)
- Michelangelo's David (E22) (Paoletti and Bagemihl, 2015)
- Einstein's Theory of General Relativity (E89) (Hartle, 2003)
- the taxon 'Fringilla coelebs Linnaeus,1758' (E55) (Sinkevicius and Narusevicius, 2002)

In first-order logic:

E71(x) ⇒ E70(x)

Properties:

P102 has title (is title of): E35 Title
(P102.1 has type: E55 Type)
P103 was intended for (was intention of): E55 Type

E73 Information Object

Subclass of:

E89 Propositional Object
E90 Symbolic Object

Superclass of:

E29 Design or Procedure
E31 Document
E33 Linguistic Object
E36 Visual Item

Scope note:

This class comprises identifiable immaterial items, such as poems, jokes, data sets, images, texts, multimedia objects, procedural prescriptions, computer program code, algorithm or mathematical formulae, that have an objectively recognizable structure and are documented as single units. The encoding structure known as a "named

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graph" also falls under this class, so that each "named graph" is an instance of E73 Information Object.

An instance of E73 Information Object does not depend on a specific physical carrier, which can include human memory, and it can exist on one or more carriers simultaneously.

Instances of E73 Information Object of a linguistic nature should be declared as instances of the E33 Linguistic Object subclass. Instances of E73 Information Object of a documentary nature should be declared as instances of the E31 Document subclass. Conceptual items such as types and classes are not instances of E73 Information Object, nor are ideas without a reproducible expression.

Examples:

- image BM000038850.JPG from the Clayton Herbarium in London (E31) (Natural History Museum, 2021)
- E. A. Poe's "The Raven" (Poe, 1869)
- the movie "The Seven Samurai" by Akira Kurosawa (Mellen, 2002)
- the text of Huray describing the Maxwell Equations (Huray, 2010)
- the Getty AAT as published as Linked Open Data, accessed 1/10/2014

In first-order logic:

E73(x) ⇒ E89(x)
E73(x) ⇒ E90(x)

Properties:

P165 incorporates (is incorporated in): E90 Symbolic Object

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.

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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:

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

In first-order logic:

E74(x) ⇒ 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:

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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:

- Maxwell’s Equations (Ball, 1962)
- the ideational contents of Aristotle’s book entitled ‘Metaphysics’ as rendered in the Greek texts translated in Oxford edition
- the underlying prototype of any “no-smoking” sign (E36)
- 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)
- the image content of the photo of the Allied Leaders at Yalta published by UPI, 1945 (E36)
- the character "Little Red Riding Hood", variants of which appear amongst others in Grimm brothers’ ‘Rotkäppchen’, other oral fairy tales and the film 'Hoodwinked'
- 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

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.

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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

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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:

- 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]
- 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)

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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) ⇒ E7(x)
P17(x,y) ⇒ E1(y)
P17(x,y) ⇒ P15(x,y)

P19 was intended use of (was made for)

Domain:

E7 Activity

Range:

E71 Human-Made Thing

Quantification:

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

Scope note:

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This property relates an instance of E7 Activity with instances of E71 Human-Made Thing, created specifically for use in the activity.

This is distinct from the intended use of an item in some general type of activity such as the book of common prayer which was intended for use in Church of England services (see *P101 had as general use (was use of)*).

Properties:

P19.1 mode of use: E55 Type

Scope note:

This property specifies the intended use of a thing employed in a particular activity.

Examples:

- Lady Diana Spencer's wedding dress (E71) was made for Wedding of Prince Charles and Lady Diana Spencer (E7) mode of use To Be Worn (E55). (Daly, 1981)

In first-order logic:

P19(x,y) ⇒ E7(x)
P19(x,y) ⇒ E71(y)
P19(x,y,z) ⇒ [P19(x,y) ∧ E55(z)]

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.

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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:

- 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) ⇒ E65(x)
P94(x,y) ⇒ E28(y)
P94(x,y) ⇒ P92(x,y)

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:

- The text entitled ‘Reach for the sky’ (E33) is about Douglas Bader (E21). (Brickhill, 2001)

In first-order logic:

P129(x,y) ⇒ E89(x)
P129(x,y) ⇒ E1(y)
P129(x,y) ⇒ P67(x,y)

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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:

- 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).
- 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:

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P138(x,y) ⇒ E36(x)
P138(x,y) ⇒ E1(y)
P138(x,y,z) ⇒ [P138(x,y) ∧ E55(z)]
P138(x,y) ⇒ P67(x,y)

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) ⇒ 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.

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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) ⇒ D11(x)

Properties:
L1 digitized (was digitized by): E18 Physical Thing
L60 documents: E1 CRM Entity

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)

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.

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Ixx Inference By Observation

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 an 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, expressed as a set of formal propositions regarded as true, are used in the same context of activity by the same Actor for a particular inference, typically related to the purpose of the observation, which is also expressed as a set 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 Oxx1 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:

Oxx1 made primary observation: O27 Observable Situation

Referred CIDOC CRMinf Properties

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

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/

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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

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