CRM geo
Spatiotemporal model

CRMgeo: a Spatiotemporal Model

An Extension of CIDOC-CRM to link the CIDOC CRM to GeoSPARQL through a Spatiotemporal Refinement

Proposal for approval by CIDOC CRM-SIG

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INTRODUCTION

1.1.1. SCOPE

This text defines the “Spatiotemporal Model”. It is a formal ontology intended to be used as a global schema for integrating spatiotemporal properties of temporal entities and persistent items. Its primary purpose is integrating all kinds of geoinformation that is available in GIS formats into CIDOC CRM representations. In order to do this it links the CIDOC CRM to the OGC standard of GeoSPARQL to make use of the conceptualizations and formal definitions that have been developed in the Geoinformation community.

It uses and extends the CIDOC CRM (ISO21127) as a general ontology of human activity, things and events happening in spacetime. It uses the same encoding-neutral formalism of knowledge representation (“data model” in the sense of computer science) as the CIDOC CRM, which can be implemented in RDFS, OWL, on RDBMS and in other forms of encoding. Since the model reuses, wherever appropriate, parts of CIDOC Conceptual Reference Model, we provide in this document also a comprehensive list of all constructs used from the CIDOC CRM 6.2 version, together with their definitions.

The background of the development of this model lies in a rising interest to enrich cultural heritage data with precise and well identified descriptions of location and geometry of sites of historical events or remains, objects and natural features. On one side there is already a tradition of more than 2 decades of using GIS systems for representing cultural-historical and archaeological data and reasoning on properties of spatial distribution, vicinity, accessibility and others. These systems tended to be closed and focused more on representing feature categories by visual symbols at different scales than integrating rich object descriptions. Cultural heritage is only a marginal application case for these systems, they have been being extremely successful in all kinds of “geosciences”, resource management and public administration.
On the other side, archives, libraries and museums keep detailed historical records of things with very poor spatial determination – frequently in the language of the source or local context, in which at their time of creation there was few ambiguity about their meaning, and frequently only wider geopolitical units, such as “Parthenon in Athens”. They rather focus on typologies, individual objects, people, kinds of events, precise dates and periods. This practice comes now in conflict when users want to integrate city plans, tourism guides, detailed excavation or restauration records, where the fact that “people know quite well where the Parthenon lies” or “you’ll see it when you go to Athens” is not helpful for advanced IT systems. But, the two traditions, the “GIS community” and the “cultural heritage community” have developed standards which precisely reflect the two different foci – the OGC/ISO Standards for Geographic Information which are the building blocks of the GeoSPARQL ontology [OGC 2012] and the ontology of the CIDOC CRM [Le Boeff et. al 2015] which is the ISO standard for representing cultural heritage information.
In an attempt to combine these two standards, we experienced a surprise: Both standards do not really match at any concepts “in between”, even though the CRM was explicitly intended to interface withOGC (Open Geospatial Consotium) Standards, and both standards do not allow for expressing objectively where something is in a way which is robust against any change of spatial scale and time. For instance, the CRM allows for specifying a “P…has former or current location”, without declaring if the location is or was the extent of the object, was within the extent of the object or included its extent. GeoSPARQL, on the other side, allows for assigning one or more precise “geometries” to a “feature”, but does not say, how the real matter of the thing with its smaller irregularities relates to those. So, for any “feature” there is a spatial scale at which a “geometry” of a detail cannot be compared any more to the geometry of the whole, nor is the temporal validity range explicitly stated although OGC Standards provide mechanisms for doing that.
What is needed is an “articulation” (linkage) of the two ontologies, i.e. a more detailed model of the overlap of both models, which allows for covering the underdetermined concepts and properties of both sides by shared specializations rather than generalizations. Therefore, we took a great step back and developed a model from the analysis of the epistemological processes of defining, using and determining places. This means that we analyzed how a question, such as “is this the place of the Varus Battle” or “is this the place where Lord Nelson died”, can be verified or falsified, including

geometric specifications. This required to identify all kinds of sources of errors, including questioning the truth of the very historical record.
Consequently, we reached at a surprisingly detailed model which seems to give a complete account of all practical components necessary to verify such a question, in agreement with the laws of physics, the practice of geometric measurement and archaeological reasoning. This model indeed appears to have the capability to link both ontologies and show the way to how to correctly reconcile data at any scale and time – not by inventing precision or truth that cannot be acquired, but by quantifying or delimiting the immanent indeterminacies, as it is good practice in natural sciences.

1.1.2. STATUS

The model presented in this document is the new version of the model published in the FORTH Technical Report 435 CRMgeo, version 1.0 (Doerr and Hiebel 2013) incorporating the changes realised in CIDOC CRM 6.2. The introduction of the E92 Spacetime Volume (replacing the SP8 Spacetime Volume) where a SP1 Phenomenal Spacetime Volume is regarded as superclass of E18 Physical Thing and E4 Period allows to change geosparql:Feature to be superclass of SP1 and E4 as well as E18 inherit the properties of Feature, in particular the elaborated topology relations that can be applied between geosparql:Feature and geosparql:Geometry. The introduction of a new SP 15 Geometry class allows for an easier implementation as it comprises the union of geometric definitions and the declarative places that they define. The changes are reflected in Figure 1. The model is not "finished" and all constructs and scope notes are open to further elaboration based on experiences gained in applying the model.

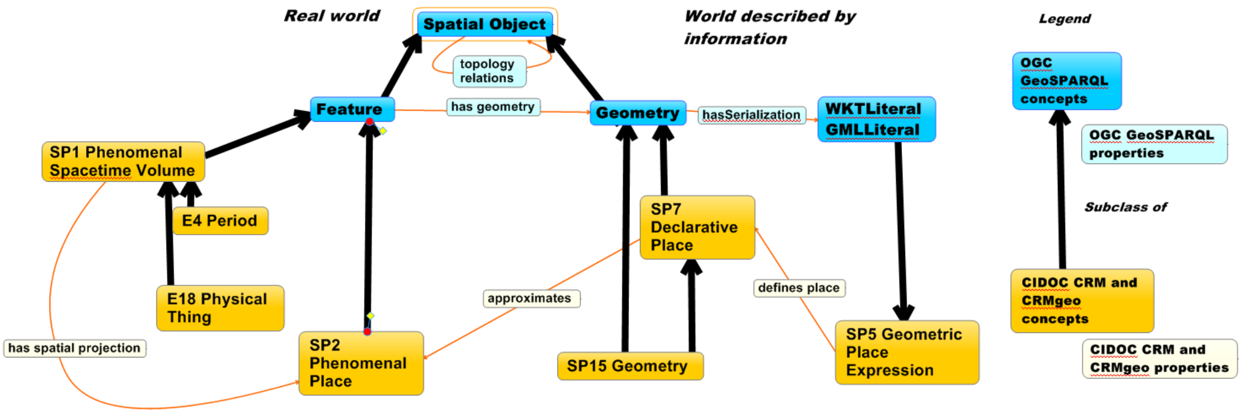

Figure 1: CIDOC CRM and CRMgeo classes and their relation to GeoSPARQL classes

1.1.3. NAMING CONVENTIONS

All the classes declared were given both a name and an identifier constructed according to the conventions used in the CIDOC CRM model. For classes that identifier consists of the letter SP followed by a number. Resulting properties were also given a name and an identifier, constructed according to the same conventions. That identifier consists of the letter Q 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. "SP" and "Q" do not have any other meaning. They correspond respectively to letters "E" and "P" in the CIDOC CRM naming conventions, where "E" originally meant "entity" (although the CIDOC CRM "entities" are now consistently called "classes"), and "P" means "property". Whenever CIDOC CRM classes are used in our model, they are named by the name they have in the original CIDOC CRM.

Letters in red colour in CRM Classes and properties are additions/extensions coming by the spatiotemporal model.

CLASS AND PROPERTY HIERARCHIES

The CIDOC CRM model declares no "attributes" at all (except implicitly in its "scope notes" for classes), but regards any information element as a "property" (or "relationship") between two classes. The semantics are therefore rendered as properties, according to the same principles as the CIDOC CRM model.

Although they do not provide comprehensive definitions, compact monohierarchical presentations of the class and property IsA hierarchies have been found to significantly aid in the comprehension and navigation of the model, and are therefore provided below.

The class hierarchy presented below has the following format:

- Each line begins with a unique class identifier, consisting of a number preceded by the letter "SP", or "E".
- A series of hyphens ("-") follows the unique class identifier, indicating the hierarchical position of the class in the IsA hierarchy.
- The English name of the class appears to the right of the hyphens.
- The index is ordered by hierarchical level, in a "depth first" manner, from the smaller to the larger sub hierarchies.
- Classes that appear in more than one position in the class hierarchy as a result of multiple inheritance are shown in an *italic typeface*.

The property hierarchy presented below has the following format:

- Each line begins with a unique property identifier, consisting of a number preceded by the letter "Q".
- A series of hyphens ("-") follows the unique property identifier, indicating the hierarchical position of the property in the IsA hierarchy.
- The English name of the property appears to the right of the hyphens.
- The domain class for which the property is declared.

1.1.4. SPATIOTEMPORAL MODEL CLASS HIERARCHY ALIGNED WITH (PART OF) CIDOC CRM CLASS HIERARCHY

E1	CRM Entity
E53	- Place
SP2	- - Phenomenal Place
SP6	- - Declarative Place
E92	- Spacetime Volume
SP1	- - Phenomenal Spacetime Volume
E4	- - - Period
E18	- - - Physical Thing
SP7	- - Declarative Spacetime Volume
E52	- Time-Span
SP13	- - Phenomenal Time-Span
SP10	- - Declarative Time-Span
E73	- Information Object
SP5	- Geometric Place Expression
SP12	- Spacetime Volume Expression
SP14	- Time Expression
E29	- Design or Procedure
SP4	- - - Spatial Coordinate Reference System
SP11	- - - Temporal Reference System
SP3	- Reference Space

1.1.5. SPATIOTEMPORAL MODEL PROPERTY HIERARCHY

P. id	Property Name	Entity – Domain	Entity - Range
Q1	occupied	E4 Period	*SP1* Phenomenal Spacetime Volume
Q2	occupied	E18 Physical Thing	*SP1* Phenomenal Spacetime Volume
Q3	has temporal projection	SP1 Phenomenal Spacetime Volume	*SP13* Phenomenal Time-Span
Q4	has spatial projection	SP1 Phenomenal Spacetime Volume	SP2 Phenomenal Place
Q5	defined in	E53 Place	SP3 Reference Space
Q6	is at rest in relation to	SP3 Reference Space	E18 Physical Thing
Q7	describes	SP4 Spatial Coordinate Reference System	SP3 Reference Space
Q8	is fixed on	SP4 Spatial Coordinate Reference System	E26 Physical Feature
Q9	is expressed in terms of	E94 Space Primitive	SP4 Spatial Coordinate Reference System
Q10	defines place	E94 Space Primitive	SP6 Declarative Place
Q11	approximates	SP6 Declarative Place	E53 Place
Q12	approximates	SP7 Declarative Spacetime Volume	E92 Spacetime Volume
Q13	approximates	SP10 Declarative Time-Span	E52 Time-Span
Q14	defines time	SP14 Time Expression	SP10 Declarative Time-Span
Q15	is expressed in terms of	SP14 Time Expression	SP11 Temporal Reference System
Q16	defines spacetime volume	SP12 Spacetime Volume Expression	SP7 Declarative Spacetime Volume
Q17	is expressed in terms of	SP12 Spacetime Volume Expression	SP11 Temporal Reference System
Q18	is expressed in terms of	SP12 Spacetime Volume Expression	SP4 Spatial Coordinate Reference System
Q19	has reference event	SP11 Temporal Reference System	E5 Event

SPATIOTEMPORAL MODEL CLASS DECLARATION

The classes are comprehensively declared in this section using the following format:

- Class names are presented as headings in bold face, preceded by the class's unique identifier;
- The line “Subclass of:” declares the superclass of the class from which it inherits properties;
- The line “Superclass of:” is a cross-reference to the subclasses of this class;
- The line “Scope note:” contains the textual definition of the concept the class represents;
- The line “Examples:” contains a bulleted list of examples of instances of this class.
- The line “Properties:” declares the list of the class's properties;
- Each property is represented by its unique identifier, its forward name, and the range class that it links to, separated by colons;
- Inherited properties are not represented;
- Properties of properties, if they exist, are provided indented and in parentheses beneath their respective domain property.

SP1 Phenomenal Spacetime Volume

Subclass of: E2 Temporal Entity,
E92 Spacetime volume
Feature

Superclass of: E4 Period
E18 Physical Thing

Scope note: This class comprises the 4 dimensional point sets (volumes) (S) which material phenomena (I) occupy in Space-Time (S). An instance of S1 Space Time Volume represents the true (I) extent of an instance of E4 Period in spacetime or the true (I) extent of the trajectory of an instance of E18 Physical Thing during the course of its existence, from production to destruction. A fuzziness of the extent lies in the very nature of the phenomenon, and not in the shortcomings of observation (U). The degree of fuzziness with respect to the scale of the phenomenon may vary widely, but the extent is never exact in a mathematical sense. According to modern physics, points in space-time are absolute with respect to the physical phenomena happening at them, regardless the so-called Galilean relativity of spatial or temporal reference systems in terms of which an observer may describe them. Following the theory, points relative to different spatial or temporal reference systems can be related if common points of phenomena in space-time are known in different systems. Instances of SP1 Phenomenal Space-Time Volume are sets of such absolute space-time points of phenomena (I).The (Einstein) relativity of spatial and temporal distances is of no concern for the scales of things in the cultural-historical discourse, but does not alter the above principles. The temporal projection of an instance of SP1 Phenomenal Space-Time Volume defines an E52 Time-Span while its spatial projection defines an SP2 Phenomenal Place. The true location of an instance of E18 Physical Thing during some time-span can be regarded as the spatial projection of the restriction of its trajectory to the respective time-span.

Examples:

- The Space Time Volume of the Event of Ceasars murdering
- The Space Time Volume where and when the carbon 14 dating of the "Schoeninger Speer II" in 1996 took place
- The spatio-temporal trajectory of the H.M.S. Victory from its building to its actual location
- The Space Time Volume of the temple in Abu Simbel before its removal

Properties:

Q3 has temporal projection: SP13 Phenomenal Time-Span

Q4 has spatial projection: SP2 Phenomenal Place

SP2 Phenomenal Place

Subclass of: E53 Place

Scope note: This class comprises instances of E53 Place (S) whose extent (U) and position is defined by the spatial projection of the spatiotemporal extent of a real world phenomenon that can be observed or measured. The spatial projection depends on the instance of S3 Reference Space onto which the extent of the phenomenon is projected. In general, there are no limitations to the number of Reference Spaces one could regard, but only few choices are relevant for the cultural-historical discourse. Typical for the archaeological discourse is to choose a reference space with respect to which the remains of some events would stay at the same place, for instance, relative to the bedrock of a continental plate. On the other side, for the citizenship of babies born in aeroplanes, the space in which the boundaries of the overflown state are defined may be relevant (I). Instances of SP2 Phenomenal Place exist as long as the respective reference space is defined. Note that we can talk in particular about what was at a place in a country before a city was built there, i.e., before the time the event occurred by which the place is defined, but we cannot talk about the place of earth before it came into existence due to lack of a reasonable reference space (E).

Examples:

- The place where the murder of Ceasar happened
- Place on H.M.S. Victory at which Nelson died
- The Place of the Varus Battle
- The volume in space of my vine glass
- The place the H.M.S Victory occupied over the seafloor when Nelson died

- The space enclosed by this room
- The space in borehole Nr. 405

SP3 Reference Space

Subclass of: E1 CRM Entity

Scope note: This class comprises the (typically Euclidian) Space (S) that is at rest (I) in relation to an instance of E18 Physical Thing and extends (U) infinitely beyond it. It is the space in which we typically expect things to stay in place if no particular natural or human distortion processes occur. This definition requires that at least essential parts of the respective physical thing have a stability of form. The degree of this stability (e.g., elastic deformation of a ship on sea, landslides, geological deformations) limits the precision to which an instance of SP3 Reference Space is defined. It is possible to construct types of (non Euclidian) reference spaces which adapt to elastic deformations or have other geometric and dynamic properties to adapt to changes of form of the reference object, but they are of rare utility in the cultural-historical discourse.

An instance of SP3 Reference Space begins to exist with the largest thing that is at rest in it and ceases to exist with its E6 Destruction. If other things are at rest in the same space and their time-span of existence falls within the one of the reference object, they share the same reference space (I). It has therefore the same temporal extent (time-span of existence) as the whole of the E18 Physical Things it is at rest with (E).

Examples:

- The Space inside and around H.M.S. Victory while it is moving through the Atlantic Ocean
- The Space inside and around the Eurasian Continental Plate
- The Space inside and around the Earth
- The Space inside and around the Solar system

Properties:

Q6 is at rest in relation to: **E18** Physical Thing

SP4 Spatial Coordinate Reference System

Subclass of: E29 Design or Procedure

Scope note: This class compromises systems that are used to describe locations in a SP3 Reference Space (S). An instance of SP4 Spatial Coordinate Reference System is composed of two parts: The first is a Coordinate System which is a set of coordinate axes with specified units of measurement and axis directions. The second part is a set of reference features at rest in the Reference Space it describes in the real world that relate the Coordinate System to real world locations (U) and fix it with respect to the reference object of its Reference Space . In surveying and geodesy, instance of SP4 Spatial Coordinate Reference System are called a datum. In the case of spatial coordinate reference systems for the earth the datum consists of the reference points and an ellipsoid that approximates the shape of the earth. National systems often use ellipsoids that approximate their territory best and shift them in an appropriate position relative to the earth while WGS84 is an ellipsoid for the whole earth and used in GPS receivers. In engineering a datum is a reference feature of an object used to create a reference system for measurement.The set of reference features in the

real world are subset of E26 Physical Feature that are within the described reference space at rest and pertain to the E18 Physical Thing the reference space is at rest with.
SP4 Spatial Coordinate Reference Systems have a validity for a certain spatial extent of the SP3 Reference Space and in addition a temporal validity. The combination of coordinate reference system and datum provides a unique identity (I). SP4 Spatial Coordinate Reference Systems may be defined for the earth, moving objects like planes or ships, linear features like boreholes or local systems. If there is a standardised identifier system available, such as EPSG codes, it should be used.

Examples:

- Longitude-Latitude(ellipsoidal Coordinate System) in WGS84 (Datum)
- EPSG 3241
- the coordinate system to describe locations on H.M.S. Victory taking the deck foundation of the middle mast as origin, the mast as z axis, the line at right angle to the bow line as x axis and a right angle to both as y axis.
- The printed lines of the millimeter paper on which an archaeological feature is drawn

Properties:

Q7 describes: SP3 Reference Space

Q8 is fixed on **E26** Physical Feature

SP5 Geometric Place Expression

Subclass of: E73 Information Object ,
E47 Spatial Coordinates,
Geometry ,
E94 Space Primitive

Scope note: This class comprises definitions of places by quantitative expressions. An instance of SP5 Geometric Place Expression can be seen as a prescription of how to find the location meant by this expression in the real world (S), which is based on measuring where the quantities referred to in the expression lead to, beginning from the reference points of the respective reference system.
A form of expression may be geometries or map elements defined in a SP4 Spatial Coordinate Reference System that unambiguously identify locations in a SP3 Reference Space. Other forms may refer to areas confined by imaginary lines connecting Phenomenal Places such as trees, islands, cities, mountain tops.
The identity of a SP5 Place Expression is based on its script or symbolic form (I). Several SP5 Place Expressions can denote the same SP6 Declarative Place .
Instances of SP5 Geometric Place Expressions that exist in one SP4 Spatial Coordinate Reference System can be transformed to geometries in other SP4 Spatial Coordinate Reference System if there is a known and valid transformation. The product of the transformation in general defines a new instance of SP6 Declarative Place , albeit close to the source of the transformation. This can be due to distortions resulting from the transformation and the limited precision by which the relative position of the reference points differing between the respective reference systems are determined.

Examples:

- Coordinate Information in GML like <gml:Point gml:id="p21" srsName="http://www.opengis.net/def/crs/EPSG/0/4326"> <gml:coordinates>45.67, 88.56</gml:coordinates> </gml:Point>
- The expression of a polygon defining the extent of France

Properties:

Q9 is expressed in terms of: **SP4** Spatial Coordinate Reference System
Q10 defines place: **SP6** Declarative Place

SP6 Declarative Place

Subclass of: E53 Place
E89 Propositional Object
Geometry

Superclass of: SP15 Geometry

Scope note: This class comprises instances of E53 Place (S) whose extent (U) and position is defined by an E94 Space Primitive (S). There is one implicit or explicit SP3 Reference Space in which the SP5 Geometric Place Expression describes the intended place. Even though SP5 Geometric Place Expressions have an unlimited precision, measurement devices and the precision of the position of reference features relating the SP4 Spatial Coordinate Reference System to a SP3 Reference Space impose limitations to the determination of a SP6 Declarative Place in the real world (U).
Several SP5 Geometric Place Expressions may denote the same SP6 Declarative Place if their precision falls within the same range (I).
Instances of SP6 Declarative Places may be used to approximate instances of E53 Places or parts of them. They may as well be used to define the location and spatial extent of property rights or national borders.

Examples:

- the place defined by <gml:Point gml:id="p21" srsName="http://www.opengis.net/def/crs/EPSG/0/4326"> <gml:coordinates>45.67, 88.56</gml:coordinates> </gml:Point>
- the place defined by a line approximating the Danube river
- The place of the Orinoco river defined in the map of Diego Ribeiro
- the place defined through a polygon that represents the boundaries of the
- UK in the year 2003

Properties:

Q11 approximates: **E53** Place

SP7 Declarative Spacetime Volume

Subclass of: **E92** Spacetime Volume
E89 Propositional Object
Geometry

Scope note: This class comprises instances of SP8 Spacetime Volumes (S) whose temporal and spatial extent (U) and position is defined by a SP12 Spacetime Volume Expression. There is one implicit or explicit SP3 Reference Space in which the SP12 Spacetime Volume Expression describes the intended Spacetime Volume. As we restrict the model to Galilean physics and explicitly exclude systems with velocities close to the speed of light we do not model a “Reference Time” as it would be necessary for relativistic physics. This implies that there is only one Reference Time.

Even though SP12 Spacetime Volume Expressions have an unlimited precision, measurement devices and the precision of the position of reference features relating the SP4 Spatial Coordinate Reference System to a SP3 Reference Space impose limitations to the determination of the spatial part of a SP7 Declarative Spacetime Volume in the real world (U).
The same limitation to precision is true for the temporal part of a SP7 Declarative Spacetime Volume due to precision of time measurement devices and of the determination of the reference event of a SP11 Temporal Reference System.
Several SP12 Spacetime Volume Expressions may denote the same SP7 Declarative Spacetime Volume if their precision falls within the same range (I).
Instances of SP7 Declarative Spacetime Volumes may be used to approximate instances of SP8 Spacetime Volumes or parts of them. They may as well be used to define the spatial and temporal extent of property rights or national borders.

Examples:

- the spacetime volume defined by a polygon approximating the Danube river flood in Austria between 6th and 9th of August 2002
- the spacetime volume of the Orinoco river in 1529 defined in the map of Diego Ribeiro in 1529
- the spacetime volume representing the boundaries of the UK from 1900-1950

Properties:

Q12 approximates: **E92** Spacetime Volume

SP10 DeclarativeTime-Span

Subclass of: E52 Time-Span
E89 Propositional Object
Geometry

Scope note: This class comprises instances of E52 Time-Spans that represent the Time Span defined by a SP 14 Time Expression. Thus they derive their identity through an expression defining an extent in time. Even though SP10 Declarative Time Spans have an unlimited precision, measurement devices and the possible precision within the SP11 Temporal Reference System impose limitations to the determination of a SP10 Declarative Time Span. The accuracy of a SP10 Declarative Time Spans depends upon the documentation and measurement method.
SP10 Declarative Time Spans may be used to approximate actual (phenomenal) Time-Spans of temporal entities.

Examples:

- Extent in time defined by the expression “1961”
- Extent in time defined by the expression “From 12-17-1993 to 12-8-1996”
- Extent in time defined by the expression “14h30 – 16h22 4th July 1945”

Properties:

Q13 approximates: E52 Time-Span

SP11 Temporal Reference System

Subclass of: E29 Design or Procedure

Scope note: This class compromises systems(S) that are used to describe positions and extents in a Reference Time. If relativistic effects are negligible in the wider spacetime area of interest and the speeds of associated things, then there is only one unique global reference time. The typical way to measure time is to count the cycles of a periodic process for which we have a hypothesis of constant frequency, such as oscillations of a crystal, molecular arrangement, rotation of earth around itself or around the sun. The origin for a Temporal Reference System is fixed on a reference event. As long as the number of cycles passed from that reference event until now are known, the temporal reference system exists (E) and expressions in this Reference System can be interpreted with respect to the Reference Time.

A temporal reference system represents time as a continuous linear interpolation over the infinit series of cycles extended from the reference event to he past and the future, regardless of the temporal position of the mathematical point zero of an instance of SP14 Time Expression, such for instance the gregorian calender begins with the event an arbitrary positiong the point zero as beeing the date of the „Birth of Christ". The actual date of birth of christ is regarded to be unknown and therefor is not the reference event.

The identity of a Temporal Reference System is defined through the type of periodic process it is based on, the reference event and through the distance of the reference event to the position of the mathematical point zero (I).

A value in the Reference Time is a temporal position measured relative to a temporal reference system. ISO 8601 specifies the use of the Gregorian Calendar and 24 hour local or Coordinated Universal Time (UTC) for information interchange.

In ISO 19108 three common types of temporal reference systems are explicitly stated: calendars (used with clocks for greater resolution), temporal coordinate systems, and ordinal temporal reference systems.

Calendars and clocks are both based on interval scales. A calendar is a discrete temporal reference system that provides a basis for defining temporal position to a resolution of one day. A clock provides a basis for defining temporal position within a day. A clock must be used with a calendar in order to provide a complete description of a temporal position within a specific day. Every calendar provides a set of rules for composing a calendar date from a set of elements such as year, month, and day. In every calendar, years are numbered relative to the date of a reference event that defines a calendar era [ISO 19108].

Specifying temporal position in terms of calendar date and time of day complicates the computation of distances between points and the functional description of temporal operations. A temporal coordinate system may be used to support applications of this kind. [ISO 19108].

Ordinal temporal reference systems as specified in ISO 19108 are no instances of SP11 Temporal Reference Systems as they do not define cycles of a periodic process but define a system of time intervals based on reverence periods related to certain natural or cultural phenomena.

Examples:

- Gregorian Calendar
- Coordinated Universal Time (UTC)
- Julian date
- Greenwich time
- ISO 8601

Properties:

Q19 has reference event: E5 Event

SP12 Spacetime Volume Expression

Subclass of: E59 Primitive Value

Scope Note: This class comprises instances of E59 Primitive Value for spacetime volumes that should be implemented with appropriate validation, precision, interval logic and reference systems to express date ranges and geometries relevant to cultural documentation. A Spacetime Volume Expression may consist of one expression including temporal and spatial information like in GML or a different form of expressing spacetime in an integrated way like a formula containing all 4 dimensions.
A Spacetime Volume Expression defines a SP7 Declarative Spacetime Volume, which means that the identity of the Spacetime Volume is derived from its geometric and temporal definition. This declarative Spacetime Volume allows for the application of all Spacetime Volume properties to relate phenomenal Spacetime Volumes of Periods and Physical Things to propositions about their spatial and temporal extents.

Examples:

- Spatial and temporal information in KML for the maximum extent of the Byzantine Empire

```
<Placemark>
    <name> Byzantine Empire </name>
    <styleUrl>#style_1</styleUrl>
    <TimeSpan>
            <begin>330</begin>
            <end>1453</end>
    </TimeSpan>
<Polygon><altitudeMode>clampToGround</altitudeMode><outerBoundaryIs><Li
nearRing>
<coordinates>18.452787460,40.85553626,0        17.2223187,40.589098,........0
17.2223,39.783
</coordinates>
</Polygon>
</Placemark>
```

- a spacetime volume expressed in Geography Markup Language (GML) defining the spatial extent of France from 1792-1816 giving one spatial extent for each year

Properties:

Q16 defines spacetime volume: SP7 Declarative Spacetime Volume

Q17 is expressed in terms of: SP11 Temporal Reference System

Q18 is expressed in terms of: SP4 Spatial Coordinate Reference System

SP13 Phenomenal Time-Span

Subclass of: E52 Time-Span

Scope note: This class comprises instances of E52 Time-Spans whose extent (U) and position is defined by the temporal projection of the spatiotemporal extent that can be observed or measured. Thus they derive their identity through the extent in time of a real world phenomenon (I).

Examples:

- Duration of the phenomenal temporal extent of the Trafalgar battle
- The real duration of the Ming Dynasty
- The real extent of the lifetime of Ceasar starting with his birth and ending with his death

SP14 Time Expression

Subclass of: E73 Information Object
E49 Time Appellation
Geometry
E61 Time Primitive

Scope note: This class comprises definitions of temporal extents by quantitative expressions(S). An instance of SP14 Time Expression defines a declarative temporal interval using a temporal reference system. The identity of a SP14 Time Expression is based on its script or symbolic form (I). Several SP14 Time Expressions can denote the same SP10 Declarative Time-Span.
Instances of SP14 Time Expression that exist in one SP11 Temporal Reference System can be transformed to time expressions in other SP11 Temporal Reference Systems if there is a known and valid transformation.

Examples:

- Temporal information in GML
  <gml:validTime><gml:TimeInstant>
  <gml:timePosition>2005-11-28T13:00:00Z</gml:timePosition>
  </gml:TimeInstant></gml:validTime>
- 1961
- From 12-17-1993 to 12-8-1996
- 14h30 – 16h22 4th July 1945
- 9.30 am 1.1.1999 to 2.00 pm 1.1.1999

Properties:

Q14 defines time: SP10 Declarative Time-Span

Q15 is expressed in terms of: SP11 Temporal Reference System

SP15 Geometry

Subclass of: SP6 Declarative Place
Geometry

Scope note: This class comprises the union of geometric definitions and the declarative places that they define. It is equivalent to the geometry class of GeoSPARQL (http://www.opengis.net/ont/geosparql#Geometry)

SPATIOTEMPORAL PROPERTY DECLARATION

The properties of the CRM spatial refinement are comprehensively declared in this section using the following format:

- Property names are presented as headings in bold face, preceded by unique property identifiers;
- The line “Domain:” declares the class for which the property is defined;
- The line “Range:” declares the class to which the property points, or that provides the values for the property;
- The line “Quantification:” declares the possible number of occurrences for domain and range class instances for the property. Possible values are: 1:many, many:many, many:1;
- The line “Scope note:” contains the textual definition of the concept the property represents;

Q1 occupied

Domain: E4 Period

Range: SP1 Phenomenal Spacetime Volume

Quantification: many to one, necessary (1,1:0,n)
Scope note: This property associates an instance of E4 Period with the 4 dimensional point sets (volumes) in spacetime that it occupied. This instance of SP1 Phenomenal Spacetime Volume includes the trajectories of the participating physical things during their participation in the instance of E4 Period, the open spaces via which they 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, such as the air in a meeting room transferring the voices. It also comprises the areas controlled by some military power. Therefore instances of E4 Period have fuzzy boundaries in spacetime.

Q2 occupied

Domain: E18 Physical Thing

Range: SP1 Phenomenal Spacetime Volume

Quantification: many to one, necessary (1,1:0,n)
Scope note: This property describes the 4 dimensional point sets (volumes) in spacetime that the trajectory of an instance of E18 Physical Thing occupies in spacetime in the course of its existence. We include in the occupied space the space filled by the matter of the physical thing and all inner spaces not accessible in regular function.

Q3 has temporal projection

Domain: SP1 Phenomenal Spacetime Volume

Range: S13 Phenomenal Time-Span

Quantification: one to one (1,1:1,1)
Scope note: This property describes the temporal projection of an instance of a SP1 Phenomenal Spacetime Volume. The property P4 has time-span is a shortcut of the more fully developed path from E4 Period through Q1 occupied, SP1 Phenomenal Spacetime Volume Q3 has temporal projection to E52 Time

Span.This property can be extended in a future model to a ternary (3-ary) relationship describing the temporal projection under a spatial constraint.

Q4 has spatial projection

Domain: SP1 Phenomenal Spacetime Volume

Range: SP2 Phenomenal Place

Quantification: one to many, necessary, dependent (1,n:1,1)
Scope note: This property describes the spatial projection of an instance of a SP1 Phenomenal Spacetime Volume on an instance of SP2 Phenomenal Place. Even though the projection of a spacetime volume to one instance of SP3 Reference Space is unique, each reference space gives rise to another projection. The projections overlap at the time of the spacetime volume, the respective instances of SP2 Phenomenal Place may later drift apart, or earlier be yet apart.
The property P7 took place at is a shortcut of the more fully developed path from E4 Period through Q1 occupied, SP1 Phenomenal Spacetime Volume Q4 has spatial projection to SP2 Phenomenal Place. This property can be extended in a future model to a ternary (3-ary) relationship describing the spatial projection under a temporal constraint.

Q5 defined in

Domain: E53 Place

Range: SP3 Reference Space

Quantification: many to one, necessary (1,1:0,n)
Scope note: This property associates an instance of E53 Place with the instance of SP3 Reference Space it is defined in.

Q6 is at rest in relation to

Domain: SP3 Reference Space

Range: E18 Physical Thing

Quantification: many to many, necessary, dependent (1,n:1,n)
Scope note: This property associates an instance of SP3 Reference Space with the instance of E18 Physical Thing that is at rest in it. For all instances of E18 Physical Thing exist at least one reference space it is at rest with because of their relative stability of form. Larger constellations of matter may comprise many physical features that are at rest with them.

Q7 describes

Domain: SP4 Spatial Coordinate Reference System

Range: SP3 Reference Space

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

Scope note: This property associates an instance of SP4 Spatial Coordinate Reference System with the instance of SP3 Reference Space for which it can be used to describe locations.

Q8 is fixed on

Domain: SP4 Spatial Coordinate ReferenceSystem

Range: E26 Physical Feature

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

Scope note: This property defines the physical reference features that ground a spatial coordinate reference system in the real world.
In surveying and geodesy this is part of the datum definition and is often a point identified by a physical feature on earth (sometimes monuments) where the earth approximation ellipsoid touches the earth and one axis of the ellipsoid runs through.

Q9 is expressed in terms of

Domain: E94 Space Primitive

Range: SP4 Spatial ReferenceSystem

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

Scope note: This property defines the coordinate reference system in terms of which a Space Primitive is formulated.

Q10 defines place

Domain: E94 Space Primitive

Range: SP6 Declarative Place

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

Scope note: This property associates an instance of SP5 Geometric Place Expression with the instance of SP6 Declarative Place it defines. Syntactic variants or use of different scripts may result in multiple instances of SP5 Geometric Place Expression defining exactly the same place. Transformations between different reference systems in general result in new definitions of places approximating each other.

Q11 approximates

Domain: SP6 Declarative Place

Range: E53 Place

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

Scope note: This property approximates an E53 Place which is defined in the same reference space.
The property does not state the quality or accuracy of the approximation, but states the intention to approximate the place.

Q12 approximates

Domain: SP7 Declarative Spacetime Volume

Range: **E92** Spacetime Volume

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

Scope note: This property approximates a Spacetime Volume. The property does not state the quality or accuracy of the approximation, but states the intention to approximate the spacetime volume.

Q13 approximates

Domain: SP10 Declarative Time-Span

Range: E52 Time-Span

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

Scope note: This property approximates a E52 Time-Span. The property does not state the quality or accuracy of the approximation, but states the intention to approximate the time span .

Q14 defines time

Domain: SP14 Time Expression

Range: SP10 Declarative Time-Span

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

Scope note: This property associates an instance of SP14 Time Expression with the instance of SP10 Declarative Time Span it defines. Syntactic variants or use of different scripts may result in multiple instances of SP14 Time Expression defining exactly the same time span. Transformations between different temporal reference systems in general result in new definitions of time spans approximating each other.

Q15 is expressed in terms of

Domain: SP14 Time Expression

Range: SP11 Temporal Reference System

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

Scope note: This property defines the temporal reference system in terms of which an SP14 Time Expression is formulated.

Q16 defines spacetime volume

Domain: SP12 Spacetime Volume Expression

Range: SP7 Declarative Spacetime Volume

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

Scope note: This property associates an instance of SP12 Spacetime Volume Expression with the instance of SP7 Declarative Spacetime Volume it defines. Syntactic variants or use of different scripts may result in multiple instances of SP12 Spacetime Volume Expressions defining exactly the same SP7 Declarative Spacetime Volume.

Transformations between different temporal or spatial reference systems in general result in new definitions of Spacetime Volumes approximating each other.

Q17 is expressed in terms of

Domain: SP12 Spacetime Volume Expression

Range: SP11 Temporal Reference System

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

Scope note: This property defines the temporal reference system in terms of which a SP12 Spacetime Volume Expression is formulated.

Q18 is expressed in terms of

Domain: SP12 Spacetime Volume Expression

Range: SP4 Spatial Coordinate ReferenceSystem

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

Scope note: This property defines the spatial coordinate reference system in terms of which a SP12 Spacetime Volume Expression is formulated.

Q19 has reference event

Domain: SP11 Temporal Reference System

Range: E5 Event

Quantification: one to many (1,1:1,n)

Scope note: This property defines the reference event for a SP11 Temporal Reference System

REFERRED CIDOC CRM CLASSES

E1 CRM Entity

Superclass of: E2 Temporal Entity
E52 Time-Span
E53 Place
E54 Dimension
E77 Persistent Item

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:

1. Identification by name or appellation, and in particular by a preferred identifier
2. Classification by type, allowing further refinement of the specific subclass an instance belongs to
3. Attachment of free text for the expression of anything not captured by formal properties

With the exception of E59 Primitive Value, all other classes within the CRM are directly or indirectly specialisations of E1 CRM Entity.

Examples:

- the earthquake in Lisbon 1755 (E5)

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

E4 Period

Subclass of: E2 Temporal Entity,
E92 Spacetime volume
Feature

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 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 E67 Birth can be seen as both an atomic E5 Event and as an E4 Period that consists of multiple activities performed by multiple instances of E39 Actor.

As the actual extent of an 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 CRMgeo (Doerr and Hiebel 2013). By virtue of this multiple inheritance we can discuss the physical extent of an 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 phenomena while a 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.

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 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.

Another specific case of an E4 Period is the set of activities and phenomena associated with a settlement, such as the populated period of Nineveh.

Examples:

- Jurassic
- European Bronze Age
- Italian Renaissance
- Thirty Years War
- Sturm und Drang
- Cubism

In First Order Logic:

E4(x) ⊃ E2(x)
E4(x) ⊃ 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 changes of states in cultural, social or physical systems, regardless of scale, brought about by a series or group of coherent physical, cultural, technological or legal phenomena. Such changes of state will affect instances of E77 Persistent Item or its subclasses.

The distinction between an E5 Event and an E4 Period is partly a question of the scale of observation. Viewed at a coarse level of detail, an E5 Event is an 'instantaneous' change of state. At a fine level, the E5 Event can be analysed into its component phenomena within a space and time frame, and as such can be seen as an E4 Period. The reverse is not necessarily the case: not all instances of E4 Period give rise to a noteworthy change of state.

Examples:

- the birth of Cleopatra (E67)
- the destruction of Herculaneum by volcanic eruption in 79 AD (E6)
- World War II (E7)
- the Battle of Stalingrad (E7)
- the Yalta Conference (E7)
- my birthday celebration 28-6-1995 (E7)
- the falling of a tile from my roof last Sunday
- the CIDOC Conference 2003 (E7)

Properties:

P11 had participant (participated in): E39 Actor

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

E18 Physical Thing

Subclass of: E72 Legal Object
E92 Spacetime Volume
Feature

Superclass of: E19 Physical Object
E24 Physical Man-Made Thing
E26 Physical Feature

Scope Note: This class comprises all persistent physical items with a relatively stable form, man-made or natural.

Depending on the existence of natural boundaries of such things, the 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, 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. Physical things consisting of aggregations of physically unconnected objects, such as a set of chessmen, occupy a number of individually contiguous spacetime volumes equal to the number of unconnected objects that constitute the set.

We model E18 Physical Thing to be a subclass of E72 Legal Object and of E92 Spacetime volume. The latter is intended as a phenomenal spacetime volume as defined in CRMgeo (Doerr and Hiebel 2013). By virtue of this multiple inheritance we can discuss the physical extent of an E18 Physical Thing 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 E18 Physical Thing is matter while a spacetime volume is an aggregation of points in spacetime. However, the real spatiotemporal extent of an instance of E18 Physical Thing 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 E18 Physical Thing. Therefore this multiple inheritance is unambiguous and effective and furthermore corresponds to the intuitions of natural language.

The CIDOC CRM is generally not concerned with amounts of matter in fluid or gaseous states.

Examples:

- the Cullinan Diamond (E19)
- the cave "Ideon Andron" in Crete (E26)
- the Mona Lisa (E22)

In First Order Logic:

E18(x) ⊃ E72(x)
E18(x) ⊃ E92(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
P58 has section definition (defines section): E46 Section Definition
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

E26 Physical Feature

Subclass of: E18 Physical Thing
Superclass of: E25 Man-Made Feature
E27 Site

Scope Note: This class comprises identifiable features that are physically attached in an integral way to particular physical objects.

Instances of E26 Physical Feature share many of the attributes of instances of E19 Physical Object. They may have a one-, two- or three-dimensional geometric extent, but there are no natural borders that separate them completely in an objective way from the carrier objects. For example, a doorway is a feature but the door itself, being attached by hinges, is not.

Instances of E26 Physical Feature can be features in a narrower sense, such as scratches, holes, reliefs, surface colours, reflection zones in an opal crystal or a density change in a piece of wood. In the wider sense, they are portions of particular objects with partially imaginary borders, such as the core of the Earth, an area of property on the surface of the Earth, a landscape or the head of a contiguous marble statue. They can be measured and dated, and it is sometimes possible to state who or what is or was responsible for them. They cannot be separated from the carrier object, but a segment of the carrier object may be identified (or sometimes removed) carrying the complete feature.

This definition coincides with the definition of "fiat objects" (Smith & Varzi, 2000, pp.401-420), with the exception of aggregates of "bona fide objects".

Examples:

- the temple in Abu Simbel before its removal, which was carved out of solid rock
- Albrecht Duerer's signature on his painting of Charles the Great
- the damage to the nose of the Great Sphinx in Giza
- Michael Jackson's nose prior to plastic surgery

E29 Design or Procedure

Subclass of: E73 Information Object

Scope note: This class comprises documented plans for the execution of actions in order to achieve a result of a specific quality, form or contents. In particular it comprises plans for deliberate human activities that may result in the modification or production of instances of E24 Physical Thing.

Instances of E29 Design or Procedure can be structured in parts and sequences or depend on others. This is modelled using *P69 is associated with*.

Designs or procedures can be seen as one of the following:

1. A schema for the activities it describes
2. A schema of the products that result from their application.
3. An independent intellectual product that may have never been applied, such as Leonardo da Vinci's famous plans for flying machines.

Because designs or procedures may never be applied or only partially executed, the CRM models a loose relationship between the plan and the respective product.

Examples:

- the ISO standardisation procedure
- the musical notation for Beethoven's "Ode to Joy"
- the architectural drawings for the Kölner Dom in Cologne, Germany
- The drawing on the folio 860 of the Codex Atlanticus from Leonardo da Vinci, 1486-1490, kept in the Biblioteca Ambrosiana in Milan

Properties:

P68 foresees use of (use foreseen by): E57 Material

P69 is associated with: E29 Design or Procedure

(P69.1 has type: E55 Type)

E52 Time-Span

Subclass of: E1 CRM Entity

Scope note: This class comprises abstract temporal extents, in the sense of Galilean physics, having a beginning, an end and a duration.

Time Span has no other semantic connotations. Time-Spans are used to define the temporal extent of instances of E4 Period, E5 Event and any other phenomena valid for a certain time. An E52 Time-Span may be identified by one or more instances of E49 Time Appellation.

Since our knowledge of history is imperfect, instances of E52 Time-Span can best be considered as approximations of the actual Time-Spans of temporal entities. The properties of E52 Time-Span are intended to allow these approximations to be expressed precisely. An extreme case of approximation, might, for example, define an E52 Time-Span having unknown beginning, end and duration. Used as a common E52 Time-Span for two events, it would nevertheless define them as being simultaneous, even if nothing else was known.

Automatic processing and querying of instances of E52 Time-Span is facilitated if data can be parsed into an E61 Time Primitive.

Examples:

- 1961
- From 12-17-1993 to 12-8-1996
- 14h30 – 16h22 4th July 1945
- 9.30 am 1.1.1999 to 2.00 pm 1.1.1999
- duration of the Ming Dynasty

Properties:

P78 is identified by (identifies): E49 Time Appellation
P79 beginning is qualified by: E62 String
P80 end is qualified by: E62 String
P81 ongoing throughout: E61 Time Primitive
P82 at some time within: E61 Time Primitive
P83 had at least duration (was minimum duration of): E54 Dimension
P84 had at most duration (was maximum duration of): E54 Dimension
P86 falls within (contains): E52 Time-Span

E53 Place

Subclass of: E1 CRM Entity

Scope note: This class comprises extents in space, in particular on the surface of the earth, in the pure sense of physics: independent from temporal phenomena and matter.

The instances of E53 Place are usually determined by reference to the position of “immobile” objects such as buildings, cities, mountains, rivers, or dedicated geodetic marks. A Place can be determined by combining a frame of reference and a location with respect to this frame. It may be identified by one or more instances of E44 Place Appellation.

It is sometimes argued that instances of E53 Place are best identified by global coordinates or absolute reference systems. However, relative references are often more relevant in the context of cultural documentation and tend to be more precise. In particular, we are often interested in position in relation to large, mobile objects, such as ships. For example, the Place at which Nelson died is known with reference to a large mobile object – H.M.S Victory. A resolution of this Place in terms of absolute coordinates would require knowledge of the movements of the vessel and the precise time of death, either of which may be revised, and the result would lack historical and cultural relevance.

Any object can serve as a frame of reference for E53 Place determination. The model foresees the notion of a "section" of an E19 Physical Object as a valid E53 Place determination.

Examples:

- the extent of the UK in the year 2003
- the position of the hallmark on the inside of my wedding ring
- the place referred to in the phrase: “Fish collected at three miles north of the confluence of the Arve and the Rhone”
- here -> <-

Properties:

P87 is identified by (identifies): E44 Place Appellation
P89 falls within (contains): E53 Place
P121 overlaps with: E53 Place
P122 borders with: E53 Place

E59 Primitive Value

Superclass of: E60 Number

E61 Time Primitive

E62 String

E94 Space Primitive

SP12 Spacetime Volume Expression

Scope Note: This class comprises values of primitive data types of programming languages or database management systems and data types composed of such values used as documentation elements, as well as their mathematical abstractions.

They are not considered as elements of the universe of discourse this model aims at defining and analysing. Rather, they play the role of a symbolic interface between the scope of this model and the world of mathematical and computational manipulations and the symbolic objects they define and handle.

In particular they comprise lexical forms encoded as "strings" or series of characters and symbols based on encoding schemes (characterised by being a limited subset of the respective mathematical abstractions) such as UNICODE and values of datatypes that can be encoded in a lexical form, including quantitative specifications of time-spans and geometry. They have in common that instances of E59 Primitive Value define themselves by virtue of their encoded value, regardless the nature of their mathematical abstractions.

Therefore they must not be represented in an implementation by a universal identifier associated with a content model of different identity. In a concrete application, it is recommended that the primitive value system from a chosen implementation platform and/or data definition language be used to substitute for this class and its subclasses.

Examples:

- ABCDEFG (E62)
- 3.14 (E60)
- 0
- 1921-01-01 (E61)

In First Order Logic:

E59(x)

E61 Time Primitive

Subclass of: E59 Primitive Value

Scope Note: This class comprises instances of E59 Primitive Value for time that should be implemented with appropriate validation, precision and interval logic to express date ranges relevant to cultural documentation.

E61 Time Primitive is not further elaborated upon within the model.

Examples:

- 1994 – 1997
- 13 May 1768
- 2000/01/01 00:00:59.7
- 85th century BC

Properties:

Q14 defines time: SP10 Declarative Time-Span

Q15 is expressed in terms of: SP11 Temporal Reference System

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:

- Maxwell's Equations
- 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
- The image content of the photo of the Allied Leaders at Yalta published by UPI, 1945 (E38)

In First Order Logic:

$E89(x) \supset E28(x)$

Properties:

P148 has component (is component of): E89 Propositional Object

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

E92 Spacetime Volume

Subclass of: E1 CRM Entity

Superclass of: E4 Period

E18 Physical Thing

E93 Presence

Scope note: This class comprises 4 dimensional point sets (volumes) in physical spacetime regardless its true geometric form. They may derive their identity from being the extent of a material phenomenon or from being the interpretation of an expression defining an extent in spacetime. Intersections of instances of E92 Spacetime Volume, Place and Timespan are also regarded as instances of E92 Spacetime Volume. An instance of E92 Spacetime Volume is either contiguous or composed of a finite number of contiguous subsets. Its boundaries may be fuzzy due to the properties of the phenomena it derives from or due to the limited precision up to which defining expression can be identified with a real extent in spacetime. The duration of existence of an instance of a spacetime volume is trivially its projection on time.

Examples:

- the spacetime Volume of the Event of Ceasars murder
- the spacetime Volume where and when the carbon 14 dating of the "Schoeninger Speer II" in 1996 took place
- the spatio-temporal trajectory of the H.M.S. Victory from its building to its actual location
- the spacetime volume defined by a polygon approximating the Danube river flood in Austria between 6th and 9th of August 2002

In First Order Logic:

E92(x) ⊃ E1(x)

Properties:

P10 falls within (contains): E92 Spacetime Volume

P132 overlaps with: E92 Spacetime Volume

P133 is separated from: E92 Spacetime Volume

P160 has temporal projection: E52 Time-Span

P161 has spatial projection: E53 Place

E94 Space Primitive

Subclass of: E59 Primitive Value

Scope Note: This class comprises instances of E59 Primitive Value for space that should be implemented with appropriate validation, precision and references to spatial coordinate systems to express geometries on or relative to earth, or any other stable constellations of matter, relevant to cultural and scientific documentation.

An E94 Space Primitive defines an E53 Place in the sense of a declarative place as elaborated in CRMgeo (Doerr and Hiebel 2013), which means that the identity of the place is derived from its geometric definition. This declarative place allows for the application of all place properties to relate phenomenal places to their approximations expressed with geometries.

Instances of E94 Space Primitive provide the ability to link CRM encoded data to the kinds of geometries used in maps or Geoinformation systems. They may be used for visualisation of the instances of E53 Place they define, in their geographic context and for computing topological relations between places based on these geometries.

E94 Space Primitive is not further elaborated upon within this model. Statement of compatibility with OPENGIS

Examples:

- Coordinate Information in GML like <gml:Point gml:id="p21" srsName="http://www.opengis.net/def/crs/EPSG/0/4326"> <gml:coordinates>45.67, 88.56</gml:coordinates> </gml:Point>
- Coordinate Information in lat, long 48,2 13,3
- Well Known Text like `POLYGON ((30 10, 40 40, 20 40, 10 20, 30 10))`

In First Order Logic:

E94(x) ⊃ E59(x)

REFERRED GEOSPARQL CLASSES

GeoSPARQL (OGC 2012) does not provide scope notes as the CIDOC CRM but extensive descriptions to the semantics of the classes are found in the OGC standards, or respective ISO standards on geographic information. Some descriptions are cited here and the references to the sources are given. For a more details on GeoSPARQL and in particular subclasses and properties please refer to the **GeoSPARQL** documentation.

SpatialObject

Superclass of: **Feature**
Geometry

Scope note: The class SpatialObject, superclass of everything feature or geometry that can have a spatial representation.

Feature

Subclass of: **SpatialObject**

Scope note: `Feature` is defined as superclass of everything feature

Further OGC/ ISO 19100 definitions:

"A feature is an abstraction of a real world phenomenon" [ISO 19101];
A feature is a geographic feature if it is associated with a location relative to the Earth. Vector data consists of geometric and topological primitives used, separately or in combination, to construct objects that express the spatial characteristics of geographic features.
Attributes of (either contained in or associated to) a feature describe measurable or describable properties about this entity. Unlike a data structure description, feature instances derive their semantics and valid use or analysis from the corresponding real world entities' meaning.
Documenting feature instances, types, semantics and their properties is often detailed in an information model. An information model details how to take real world ideas or objects and make them useful to a computer system. In the geospatial world the focus is on depicting things in the real world as points, lines, or polygons (the geometry "primitives" we use to assemble location data about those real world objects) and their attributes (information about those objects). When linked together, a pair (geometry and attributes) representing one or more real world objects, is called a feature.
There are three popular approaches for the modeling of geospatial features.
The first models the spatial extent of a feature with point, lines, polygons, and other geometric primitives that come from a list of well-known types. Features modeled in this fashion are called "Features with Geometry."

The second approach is called a “Feature as Coverage”. This technology includes images as a special case.
The third approach is “Feature as Observation”. An Observation is an action with a result which has a value describing some phenomenon. The observation is modelled as a Feature within the context of the General Feature Model [ISO 19101, ISO 19109]. An observation feature binds a result to a feature of interest, upon which the observation was made. The observed property is a property of the feature of interest. All these primary Features types are intimately related, yet have distinct concepts (OGC 2009)

Geometry

Subclass of: **SpatialObject**

Scope note: The class Geometry, superclass of everything geometry.

Further OGC/ ISO 19100 definitions:
The Geometry class is based on the specifications in ISO 19107 (ISO 2003) and in particular of the GM_Object. GM_Object is the root class of the geometric object taxonomy and supports interfaces common to all geographically referenced geometric objects. GM_Object instances are sets of direct positions in a particular coordinate reference system. A GM_Object can be regarded as an infinite set of points that satisfies the set operation interfaces for a set of direct positions, TransfiniteSet<DirectPosition>. Since an infinite collection class cannot be implemented directly, a Boolean test for inclusion shall be provided by the GM_Object interface. This International Standard concentrates on vector geometry classes, but future work may use GM_Object as a root class without modification (ISO 2003).

LITERATURE

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