CRMinf
Argumentation model

Definition of the CRMinf
An Extension of CIDOC-CRM to support argumentation

Proposal for approval by the CIDOC CRM-SIG

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Introduction

This document describes work which uses and extends the CIDOC Conceptual Reference Model (CRM, ISO21127). The CIDOC CRM definition document should be read before this document. References to the CIDOC-CRM in this document are taken from CIDOC CRM version 7.1.2 maintained by CIDOC.

Scope

This text defines the "Argumentation Model", a formal ontology intended to be used as a global schema for integrating metadata about argumentation and inference making in descriptive and empirical sciences,[1] such as biodiversity, geology, geography, archaeology, cultural heritage, conservation, research IT environments, and research data libraries. Its primary purpose is facilitating the management, integration, mediation, interchange and access to data about reasoning, by a description of the semantic relationships between the premises, conclusions, and activities of reasoning.

It uses and extends the CIDOC CRM (ISO21127) as a general ontology of human activity, things and events happening in space-time. 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 other forms of encoding. Since the model reuses, whenever appropriate, parts of CIDOC CRM, we provide in this document also a comprehensive list of all constructs used from ISO201127 following the version 7.1.2 maintained by CIDOC.

The Argumentation Model is reducing the IAM model in Doerr, Kritsotaki and Boutsika (2011) and embedding it in the CRMsci. It simplifies IAM by making the inference structure (such as a mathematical proof) and the belief in this structure implicit to the argumentation event. It develops explicit scope notes for the concepts in this model. It maintains the flexibility of the IAM with respect to the system of belief values to be employed. It is motivated and has been validated by examples of argumentation about facts (in contrast to categorical theory building) from archaeological reasoning and reasoning on text elements and annotations in manuscripts. It takes further into account reasoning about facts in scientific data in the form of observation, measurement, data evaluation and citation in biodiversity, geology, archaeology, cultural heritage conservation, and clinical studies.

Besides application-specific extensions, this model is intended to be complemented by CRMsci, a more detailed model and extension of the CIDOC CRM for metadata about scientific observation, measurements and processed data in descriptive and empirical sciences, also currently available in a first stable version [CRMsci, version 1.2 – Doerr, M. & Kritsotaki, A. 2014].

This is an attempt to maintain a modular structure of multiple ontologies related and layered in a specialization-generalization relationship, and into relatively self-contained units with few cross-correlations into other modules, such as describing quantities. This model aims at staying harmonized with the CIDOC CRM, i.e., its maintainers submit proposals for modifying the CIDOC CRM wherever adequate to guarantee the overall consistency, disciplinary adequacy and modularity of CRM-based ontology modules.

An instance of I2 Belief comes into existence when an instance of I1 Argumentation concludes it (through one of its sub-classes, S4 Observation, I5 Inference Making, or I7 Belief Adoption). Only one E39 Actor may hold a particular instance of I2 Belief, though the E38 Actor may, of course, be an instance of E74 Group. Such an instance of E74 Group may lose or gain members (via one or more instances of E85 Joining or E86 Leaving)

[1] Descriptive sciences are all the sciences that collect, observe and describe phenomena and then find straightforward correlations between them, without a particular scientific hypothesis in mind. Empirical sciences aim to explain the observed phenomena and to draw hypothetical conclusions about their behavior and their relationships under given circumstances. Since the argumentation and inference making in both sciences is based on observation of sensory data, they can be considered to be "empirical sciences" in a wider sense. In this perspective, those sciences that perform experiments to test their conclusions about observed phenomena can be regarded as a subcategory of "empirical sciences". Thus, according to our view, descriptive and empirical sciences are not competitive but complementary.

without affecting the belief the group representatively maintains. The members supporting the common belief may not necessarily be individually convinced of it. This does not invalidate the belief of the Group.

The instance of E39 Actor that holds an instance of I2 Belief, is the same actor that carried out an I1 Argumentation, which resulted in said belief. If any other instances of E39 Actor wish to adopt the I6 Belief Value about part or all of the I4 Proposition Set attached to an instance of I2 Belief, then a new instance of I7 Belief Adoption must be used to create a new instance of I2 Belief. This new instance of I2 Belief will have the same I6 Belief Value as the original instance of I2 Belief and must share at least some of the propositions in the original I4 Proposition Set.

An instance of I2 Belief goes out of existence when the instance of E39 Actor changes its I6 Belief Value about one or more of the propositions in the associated instance of I4 Proposition Set. Should the instance of E38 Actor continue to hold the same opinion about other propositions in the associated I4 Proposition Set, then a new instance of I5 Inference Making would create a new instance of I2 Belief. The new instance of I5 Inference Making would use the original instance of I2 Belief as a premise.

Status

The model presented in this document has so far been validated in the British Museum Discovering Sloan project. This document describes a consolidated version from this experience, with the aim to present it for review and further adoption to the widest possible community. The model is not “finished”, some parts, such as the subclasses of I5 Inference Making are not fully developed in terms of properties, and all constructs and scope notes are open to further elaboration.

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, the identifier consists of the letter I, followed by a number. Resulting properties were also given a name and an identifier, constructed according to the same conventions. The identifier consists of the letter J, 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. “I” and “J” 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.

CRMinf classes and properties 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 CDOC CRM model.

Although they do not provide comprehensive definitions, compact monohierarchic 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 “I”, “S”, or “E”.
- A series of hyphens (“-”) follows the unique class identifier, indicting 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 subhierarchies.
- 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 “I”, “AP”, or “P”.
- 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.
- The range class of the property.

CRMinf class hierarchy, aligned with portions from the CRMsci and the CIDOC-CRM class hierarchies

This class hierarchy lists:

- all classes declared in CRMinf,
- all classes declared in CRMsci version 2.0 and CIDOC-CRM version 7.1.2 that are declared as superclasses of classes declared in the CRMinf,
- all classes declared in CIDOC-CRM version 7.1.2 that are either domain or range for a property declared in the CRMinf,
- all classes declared in CIDOC-CRM version 7.1.2 that are either domain or range for a property declared in CRMinf version 1.0 or CIDOC CRM version 7.1.2 that is declared as superproperty of a property declared in the CRMinf,
- all classes declared in CIDOC-CRM version 7.1.2 that are either domain or range for a property that is part of a complete path of which a property declared in CRMinf is declared to be a shortcut.

Table 1: Class Hierarchy

E1 CRM Entity
— E2 Temporal Entity
— — E4 Period
— — — E5 Event
— — — — E7 Activity
— — — — — I1 Argumentation
— — — — — — S4 Observation
— — — — — — I5 Inference Making
— — — — — — — S6 Data Evaluation
— — — — — — — S7 Simulation or Prediction
— — — — — — — I17 Categorical Hypothesis Building
— — — — — — I7 Belief Adoption
— — — — — — I15 Provenance Assessment
— — — — — — I16 Meaning Comprehension
— — — — — E13 Attribute Assignment
— I2 Belief
— — I12 Adopted Belief
— — I13 Intended Meaning Belief
— — I14 Provenance Belief
— E77 Persistent Item
— — E70 Thing
— — — E72 Legal Body
— — — — E89 Propositional Object
— — — — — E73 Information Object
— — — — — — I4 Proposition Set

— — — — — — — I10 Provenance Statement
— — — — — — — I11 Situation
— — — — I3 Inference Logic
— — — — E90 Symbolic Object
— — — — — *E73 Information Object*
— — — — — — *I4 Proposition Set*
— — — — — — *I10 Provenance Statement*
— — — — — — — *I11 Situation*
— E59 Primitive Value
— — I6 Belief Value

List of external classes used in CRMinf

Table 2: List of external classes grouped by model and ordered by model (exception: CRMbase always goes first) and then by class identifier.

Class identifier	Class name	Model	Version
E1	CRM Entity	CIDOC CRM	7.1.2
E2	Temporal Entity	CIDOC CRM	7.1.2
E4	Period	CIDOC CRM	7.1.2
E5	Event	CIDOC CRM	7.1.2
E7	Activity	CIDOC CRM	7.1.2
E13	Attribute Assignment	CIDOC CRM	7.1.2
E59	Primitive Value	CIDOC CRM	7.1.2
E77	Persistent Item	CIDOC CRM	7.1.2
E70	Thing	CIDOC CRM	7.1.2
E72	Legal Object	CIDOC CRM	7.1.2
E73	Information Object	CIDOC CRM	7.1.2
E89	Propositional Object	CIDOC CRM	7.1.2
E90	Symbolic Object	CIDOC CRM	7.1.2
S4	Observation	CRMsci	2.0
S6	Data Evaluation	CRMsci	2.0
S7	Simulation or Prediction	CRMsci	2.0

CRMinf property hierarchy, aligned with portions from the CRMsci and the CIDOC-CRM property hierarchies

This property hierarchy lists:

- all properties declared in CRMinf,
- all properties declared in CRMarchaeo version 2.0, and CIDOC-CRM version 7.1.2 that are declared as superproperties of properties declared in CRMinf,
- all properties declared in CRMarchaeo version 2.0 and CIDOC-CRM version 7.1.2 that are part of a complete path of which a property declared in CRMinf, is declared to be a shortcut.

Table 3: Property Hierarchy

Property id	**Property Name**	**Entity – Domain**	**Entity - Range**

List of external properties used in <extension name>

Table 4: List of external properties grouped by model and ordered by model (exception: CRMbase always goes first) and then by property identifier.

Property identifier	Property name	Model	Version

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CRMinf Class Declarations

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

- Class names are presented as headings in boldface, preceded by the unique identifier of the class;
- 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 the 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 “In first-order logic:” expresses the formal constraints of the class in terms of logical axioms in a First-Order Logic notation.
- The line “Properties:” declares the list of the properties for the class in question;
- 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.

I1 Argumentation

Subclass of:

E7 Activity

Superclass of:

S4 Observation
I7 Belief Adoption
I5 Inference Making

Scope note:

This class comprises the activity of making honest inferences or observations. An honest inference or observation is one in which the E39 Actor carrying out the I1 Argumentation justifies and believes that the I6 Belief Value associated with the resulting I2 Belief about the I4 Proposition Set is the correct value at the time that the activity was undertaken and that any I3 Inference Logic or methodology was correctly applied.

One instance of E39 Actor may carry out an instance of I1 Argumentation, though the E39 Actor may, of course, be an instance of E74 Group.

Examples:

- My classification and dating of this bowl (I5) (fictitious)
- My adoption of the belief that Dragendorff type 29 bowls are from the 1st Century AD (I7) (fictitious)

In First Order Logic:

I1(x) ⇒ E7(x)

Properties:

J2 concluded that (was concluded by): I2 Belief

I2 Belief

Subclass of:

E2 Temporal Entity

Superclass of:

Scope note:

This class comprises the notion that the associated I4 Proposition Set is held to have a particular I6 Belief Value by a particular E39 Actor. This can be understood as the period of time that an individual group holds a particular set of propositions to be true, false, or somewhere in between.

Examples:

- Ian Hodder's belief from 1996 on, that Floor B was earlier than wall C of building 1 in the north area of Catalhöyük (Hodder 1999).

In First Order Logic:

I2(x) ⇒ E2(x)

Properties:

J4 that (is subject of): I4 Proposition Set
J5 holds to be: I6 Belief Value

I3 Inference Logic

Subclass of:
E89 Propositional Object

Superclass of:

Scope note:
This class comprises the rules used as inputs to I5 Inference Making.

In this context, the term “logic” is used in the most general sense of the Greek term, and not in the mathematical sense only. Examples are the direct application of formal logic, mathematical theories and calculus, formal or informal default reasoning based on default values associated with categories, probabilistic reasoning-based mathematical models and assumed or observed frequencies for certain categories, application of theoretical social models and comparisons with “cultural parallels”, etc. An instance of Inference Logic could also be a reference to the exact software release of a Bayesian reasoner, a rule such as “later layers are on top of earlier layers”, or even a term like “social intuition”, if this is scholarly acceptable (after Doerr, Kritsotaki and Boutsika, 2011).

Indeed, anything that is scientifically or academically acceptable as a method for drawing conclusions may be included, for instance, human pattern recognition.

A particular instance of I3 Inference Logic would be the algorithm implemented in a particular revision of a software package.

Instances of I3 Inference Logic not only comprise the method of reasoning, but also the set of categorical laws or axioms used in the argumentation. Often, both are inextricably interwoven, for instance in a software implementation.

Examples:
- Dating using a reference typology
- Use of parallels

In First Order Logic:
I3(x) ⇒ E89(x)

Properties:

I4 Proposition Set

Subclass of: E73 Information Object

Superclass of:
I10 Provenance Statement

Scope note:
This class comprises the sets of formal, binary propositions that an I2 Belief is held about. It could be implemented as a named graph, a spreadsheet, or any other structured dataset. Regardless of the specific syntax employed, the effective propositions it contains should be made up of unambiguous identifiers, concepts of a formal ontology, and constructs of logic.

Examples:
- Francesca Bologna’s belief that Publius Cornelius Tacitus meant that “Nero was at Antium when the Great Fire broke out and did not return to Rome until the fire approached his house” (I12) *J2 that*

{Nero in July 19, 64 AD (E93 Presence)
P164 is temporally specified by: July 19, 64 AD (E52 Timespan)
P195 was a presence of: Nero Claudius Caesar Drusus Germanicus (E21 Person)
P167 was within Antium in 64AD, Italy (E53 Place)
P133 is spatiotemporally separated from: The Great Fire of Rome (E5 Event)
P1 is identified by: incendium magnum Romae (E41 Appellation)
P4 has timespan: July 19-27, 64 AD (E52 Timespan)
P7 took place at : Rome in 64AD, Italy (E53 Place)
} (Bologna 2021)

- Francesca Bologna's belief that Gaius Suetonius Tranquillus meant that Nero was singing in Rome while it was burning from July 19 in 64 AD *J15 assumed meaning*
{Nero July 19, 64 AD (E93 Presence)

P164 is temporally specified by: July 19, 64 AD (E52 Timespan)
P195 was a presence of: Nero Claudius Caesar Drusus Germanicus (E21 Person)
P167 was within Rome in 64AD, Italy (E53 Place)
P10 falls within (contains): Nero Singing (E7 Activity)
P2 has type: Singing (E55 Type)
P14 carried out by: Nero Claudius Caesar Drusus Germanicus (E21)
P4 has timespan: July 19, 64 AD (E52 Timespan)
P7 took place at: Rome in 64AD, Italy (E53 Place)
P132 spatiotemporally overlaps with: The Great Fire of Rome (E5 Event)
P1 is identified by: incendium magnum Romae (E41 Appellation)
P4 has timespan: July 19-27, 64 AD (E52 Timespan)
P7 took place at: Rome in 64AD, Italy (E53 Place)
}(I4) (Bologna 2021)

In First Order Logic:

I4(x) ⇒ E73(x)

Properties:

I5 Inference Making

Subclass of:

I1 Argumentation
E13 Attribute Assignment

Superclass of:

I17 Categorical Hypothesis Building
S6 Data Evaluation
S7 Simulation or Prediction

Scope note:

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

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

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

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

Examples:

- My classification and dating of this bowl (fictitious)

In First Order Logic:

I5(x) ⇒ I1(x)
I5(x) ⇒ E13(x)

Properties:

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

I6 Belief Value

Subclass of:

E59 Primitive Value

Superclass of:

Scope note:

This class comprises any encoding of the value of the truth of an I2 Belief. It may be expressed in terms of discrete logic, modal logic, probability, fuzziness, or any other adequate representational system.

A minimum requirement of flexibility is for three values: True; False; Unknown.

Examples:

- True
- False

In First Order Logic:

I6(x) ⇒ E59(x)

Properties:

I7 Belief Adoption

Subclass of:

I1 Argumentation

Superclass of:

Scope note:

This class comprises the action of an E39 Actor adopting propositions taken from an interpretation of the intended meaning of an instance of E73 Information Object as being true, or in some way likely to be true. The adopted propositions constitute the conclusion of the action in the form of a new instance of I12 Adopted belief of the actor adopting it.

The basis of I7 Belief Adoption is the justification of trust in the source of the adopted propositions, rather than the application of rules for inferring the respective propositions from logical remises.

Typical examples are the citation of academic papers or the reuse of datasets.

Where an instance of I7 Belief Adoption is based on personal communication (marked as *pers.comm.* in the studied text), this should be represented by using *P2 has type*: *"Pers.Comm."*, directly from the instance of I7 Belief Adoption.

Examples:

- Francesca Bologna's adoption of Tacitus' belief where Emperor Nero was when the Great Fire started. (Bologna 2021).
  [Francesca Bologna adopted Tacitus belief, as the only historian who was actually alive at the time of the Great Fire of Rome (although only 8 years old): "Nero at this time was at Antium and did not return to Rome until the fire approached his house" in: Tacitus, Publius Cornelius. The Annals. Book 15 [15.16].]

In First Order Logic:

I7(x) ⇒ I(x)

Properties:

J13 adopted interpretation (was concluded by): I12 Adopted Belief
J7 is based on evidence from (was evidence for): E73 Information Object
J15 assumed meaning (was assumed by): I13 Intended Meaning Belief
J18 assumed provenance (was assumed by): I14 Provenance Belief

I10 Provenance Statement

Subclass of:

I4 Proposition Set

Superclass of:

Scope note:

This class comprises statements about the provenance of instances of E70 Thing existing at the time of making the provenance statements. An instance of I10 Provenance Statement must contain propositions about the presence of the respective instances of E70 Thing in an event or spatiotemporal context of reference. Characteristically, it may pertain to the writing by a known author at a known or unknown date or place, or to the existence of the text known to some public, regardless of the truth of authorship.

In case that only information objects exist describing the proper thing of interest, such as a photo, or photo of a photo, of a lost archaeological object, an instance of I10 Provenance Statement should contain the relevant chain of intermediate events transferring the information from the proper thing of interest up to the extant information objects taken into account, or refer to it.

The property *J20 is about the provenance of* can be used to link the instance of I10 Provenance Statement as a whole, with the proper thing of interest. It constitutes a constraint to the provenance statement that it must contain the description of the relevant context of reference, and, if applicable, to the relevant chain of intermediate events transferring the information.

Examples:

- The statement: "The copy of Tacitus, Publius Cornelius. The Annals. Book 15 [15.6] at the hands of Francesca Bologna from the British Museum in 2021 represents a text written by

the ancient Roman historian, Publius Cornelius Tacitus."
[This statement can be represented by a set of CRM compatible propositions]
- The statement: "The Latin content of the extant book *De Vita Caesarum* attributed to Gaius Suetonius Tranquillus was published in Rome in 121 AD and its content has not been alienated in its current known form through transcription errors"
[This statement can be represented by a set of CRM compatible propositions]
- The statement: "The exemplar of the Merchant of Venice, Quarto 1 (1600), owned by the British Library, shelf number BL C.34.k.22, was published in 1600 AD by Thomas Hayes."
[This statement can be represented by a set of CRM compatible propositions]
- The statement: "The Nebra Sky Disc dates to the Early Bronze Age" (Pernicka et al. 2020).

In First Order Logic:

I10(x) ⇒ I4(x)

Properties:

J20 is about the provenance of (has provenance claim): E70 Thing

I11 Situation

Subclass of:

I4 Proposition Set

Superclass of:

Scope note:

This class comprises the persistence of particular value ranges of the properties of a particular thing or things, over a timespan. The identity of an instance of I11 Situation is given by prescribing kinds of properties and a particular timespan and optionally the spatial area. This prescription of properties enables the possibility of observing the values of those properties prescribed, that hold in the specified timespan and spatial area.

In general, there are no natural boundaries to the combination of the kinds of properties or the space and the timespan under consideration upon defining a situation, other than the interest and ability of the observer to do so. Therefore, this class is purely epistemological in nature, describing arbitrary units of observation of the world.

Examples:

- the persistence of the value of the pH for sample XIV during the period of the pH measurement, which took place one month after the application of $Ca(OH)_2$ dispersion to the sample (Giori et al. 2002).

In First Order Logic:

I11(x) ⇒ I4(x)

Properties:

I12 Adopted Belief

Subclass of:

I2 Belief

Superclass of:

Scope note:

This class comprises the notion that an instance of E39 Actor adopted the meaning of an associated instance of I4 Proposition Set by arguments of trust from a source created by another instance of E39 Actor, and holds it as being true or in some way likely to be true. This source can be documented via the property *J14 adopted interpretation of (has adopted interpretation)*. The used interpretation of the meaning of the source may be a belief of the adopting Actor or another one and can be documented as an instance of I13 Intended Meaning Belief, if this detail is relevant.

Examples:

- Francesca Bologna's belief that Nero was at Antium, when the Great Fire broke out and did not return to Rome until the fire approached his house (Bologna 2021).

In First Order Logic:

I12(x) ⇒ I2(x)

Properties:

J14 adopted interpretation of (has adopted interpretation): E73 Information Object

I13 Intended Meaning Belief

Subclass of:

I2 Belief

Superclass of:

Scope note:

This class comprises beliefs on the part of an instance of E39 Actor that a particular I4 Proposition Set formally represents (in part or in its entirety) the intended meaning that was created by another instance of E39 Actor, without considering an opinion yet about its truth or trustworthiness.

The belief constitutes an interpretation of the source. The respective proposition set can be documented using the property *J16 assumed meaning (is supposed meaning in)*, whereas the respective source can be documented via the property *J17 about (has interpretation)* and holds as being true or in some way likely to be true.

Examples:

- Francesca Bologna's belief that Publius Cornelius Tacitus meant that "Nero was at Antium when the Great Fire broke out and did not return to Rome until the fire approached his house". (Bologna 2021)
- Francesca Bologna's belief that Gaius Suetonius Tranquillus meant that "Nero was singing in Rome while it burned from July 19 in 64 AD". (Bologna 2021)

In First Order Logic:

I13(x) ⇒ I2(x)

Properties:

J16 assumed meaning (is supposed meaning in): I4 Proposition Set
J17 about (has interpretation): E73 Information Object

I14 Provenance Belief

Subclass of:

I2 Belief

Superclass of:

Scope note:

This class comprises beliefs of an Actor that a particular instance of E70 Thing, in general available to this Actor, is identical to one present in a relevant event or context of reference in the past, such as a text in a book being sufficiently identical to the one in the claimed author's original manuscript or edition in order to be used by the Actor for citation. Other examples are the provenance of archaeological objects in collections, which may pertain to the claimed excavation spot or to the inferred context of their creation.

The term "in general available" means that the thing is either physically in the hands of the actor or that the actor or an actor of their trust has the principled ability to get access to the thing. In case that only information objects exist describing the proper thing of interest, such as a photo of a lost archaeological object, an instance of Ix5 Provenance Belief should be based on arguments including references to provenance beliefs about descriptions, representations and the described things.

A formal description about the assumed provenance can be documented via the property *Jxx8 that*. Note that, depending on the intended argumentation about the respective instance of E70 Thing, different aspects of provenance may be described about the same instance of E70 Thing.

Examples:

- Francesca Bologna's belief about the authenticity of Tacitus, Publius Cornelius. The Annals. Book 15.

In First Order Logic:

I14(x) ⇒ I2(x)

Properties:

J19 that (is subject of): I10 Provenance Statement

I15 Provenance Assessment

Subclass of:

I1 Argumentation

Superclass of:

Scope note:

This class comprises activities of making arguments and concluding about the likely provenance of instances of E70 Thing existing at the time of this assessment. These activities may further be about the provenance of things referred to or represented by existing information objects, and subsequent references.

Examples:

- the assessment by Ernst Pernicka et al. about the provenance of the Nebra Sky Disc (Pernicka et al. 2020)

In First Order Logic:

I15(x) ⇒ I1(x)

Properties:

J21 concluded provenance (was assessed by): I14 Provenance Belief

I16 Meaning Comprehension

Subclass of:

I1 Argumentation

Superclass of:

Scope note:

This class comprises processes of interpreting the intended meaning of parts or the whole of the content of an instance of E73 Information Object as propositions. Such interpretations may include the disambiguation of the meaning of words and expressions, expanding abbreviations, resolving named entities, references and co-references, and complementing missing text parts, without however arguing about the actual truth of the information.

In principle, any use of an information object pertaining to its meaning implies an instance of Ix1 Meaning Comprehension. However, in practical applications, texts in natural language are often clear enough so that no explicit explanation of the interpretation is needed for the user. In such cases, there is no need to create explicit instances of Ix1 Meaning Comprehension, but the adopted belief may directly be linked via *Jxx2 adopted interpretation of (has adopted interpretation),* or the instance of Ix1 Meaning Comprehension may be made implicit to an instance of I7 Belief Adoption by multiple instantiation.

Explicit documentation of instances of Ix1 Meaning Comprehension are useful, if the interpretations are not obvious and if competing arguments about them exist.

Examples:

- My understanding of the statements about Emperor Nero's whereabouts in Rome while it was burning from July 19 in 64 AD in the extant book *De Vita Caesarum* attributed to Gaius Suetonius Tranquillus (Wikipedia, 2023).

In First Order Logic:

$I16(x) \Rightarrow I1(x)$

Properties:

J22 interpreted meaning of (was interpreted by): E73 Information Object
J23 interpreted meaning as (was interpretation by): I13 Intended Meaning Belief

I17 Categorical Hypothesis Building

Subclass of:

I5 Inference Making

Superclass of:

Scope note:

This class comprises the action of making categorical hypotheses based on inference rules and theories; By categorical hypotheses we mean assumptions about the kinds of interactions and related kinds of structures of a domain that have the character of "laws" of nature or human behavior, be it necessary or probabilistic. Categorical hypotheses are developed by "induction" from finite numbers of observation and the absence of observations of particular kinds. As such, categorical hypotheses are always subject to falsification by new evidence. Instances of S8 Categorical Hypothesis Building include making and questioning categorical hypotheses.

Examples:

- hypothesising that “no binding before the 9th century is made with spine supports” by Szirmai (S8) [documented in section 7.1 and 7.2 of “The Archaeology of Medieval bookbinding”] (Szirmai, J.A. 1999)

In First Order Logic:

$$I17(x) \Rightarrow I5(x)$$

Properties:

CRMinf Property Declarations

The properties 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 “Subproperty of:” is a cross-reference to any superproperties the property may have;
- The line “Superproperty of:” is a cross-reference to any subproperties the property may have;
- The line “Quantification:” declares the possible number of occurrences for domain and range class instances for the property.
- The line “Scope note:” contains the textual definition of the concept the property represents;
- The line “Examples:” contains a bulleted list of examples of instances of this property. If the example is also instance of a subproperty of this property, the unique identifier of the subclass is added in parenthesis. If the example instantiates two properties, the unique identifiers of both properties is added in parenthesis.
  The line “Examples:” provides illustrative examples showing how the property should be used;
- The line “In first-order logic:” expresses the formal constraints of the property in terms of logical axioms in a first-order logic notation.

J1 used as premise (was premise for)

Domain:

I5 Inference Making

Range:

I2 Belief

Subproperty of:

E7 Activity. P17 was motivated by (motivated): E1 CRM Entity

Superproperty of:

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

Quantification:

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

Scope note:

This property associates an instance of I2 Belief with the instance of I5 Inference Making that used it as a premise.

Examples:

- My classification and dating of this bowl (I5) *used as premise* my belief that Dragendorff type 29 bowls are from the 1st century AD (I2).
- My classification and dating of this bowl (I5) *used as premise* my belief in the observations of this bowl (I2).

In First Order Logic:

J1(x,y) ⇒ I5(x)
J1(x,y) ⇒ I2(y)
J1(x,y) ⇒ P17(x,y)

J2 concluded that (was concluded by)

Domain:

I1 Argumentation

Range:

I2 Belief

Subproperty of:

E2 Temporal Entity. AP24 starts (is started by): E2 Temporal Entity.

E2 Temporal Entity. P175 starts before or with the start of (starts after or with the start of): E2 Temporal Entity
E2 Temporal Entity. P175i starts after or with the start of (starts before or with the start of): E2 Temporal Entity
E2 Temporal Entity. P185 ends before the end of (ends after the end of): E2 Temporal Entity.

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I2 Belief with the instance of I1 Argumentation that concluded it.

Examples:

- Ian Hodder's re-examination, in 1996, of the physical relation of wall C and floor B of building 1 in the north area of Catalhöyük (I1) *concluded that* Ian Hodder believed from 1996 on, that Floor B was earlier than wall C of building 1 in the north area of Catalhöyük (I2) (Hodder 1999).

In First Order Logic:

J2(x,y) ⇒ I1(x)
J2(x,y) ⇒ I2(y)
J2(x,y) ⇒ AP24(x,y)
J2(x,y) ⇒ P175(x,y)
J2(x,y) ⇒ P175i(x,y)
J2(x,y) ⇒ P875(x,y)

J3 applied (was applied by)

Domain:

I5 Inference Making

Range:

I3 Inference Logic

Subproperty of:

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

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I3 Inference Logic with the instance of I5 Inference Making that used it to draw its conclusion.

Examples:

- My classification and dating of this bowl (I5) *applied* use of a typology (I3).

In First Order Logic:

J3(x,y) ⇒ J5(x)
J3(x,y) ⇒ J3(y)
J3(x,y) ⇒ P16(x,y)

J4 that (is subject of)

Domain:

I2 Belief

Range:

I4 Proposition Set

Subproperty of:

Superproperty of:

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

Scope note:
This property associates an instance of I4 Proposition Set with the instance of I2 Belief that holds an opinion about it.

Examples:
- Dragendorff's belief concerning type 29 Bowls (I2) *that* type 29 Bowls are from the 1st century AD (I4).

In First Order Logic:
J4(x,y) ⇒ I2(x)
J4(x,y) ⇒ I4(y)

J5 holds to be

Domain:
I2 Belief

Range:
I6 Belief Value

Subproperty of:

Superproperty of:

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

Scope note:
This property associates an instance of I2 Belief with the I6 Belief Value that reflects the opinion of the instance of I2 Belief about the I4 Proposition Set associated with it.

Examples:
- Dragendorff's belief that type 29 bowls are from the 1st century AD (I2) *holds to be* True (I6)

In First Order Logic:
J5(x,y) ⇒ I2(x)
J5(x,y) ⇒ I6(y)

J7 is based on evidence from (is evidence for)

Domain:
I7 Belief Adoption

Range:
E73 Information Object

Subproperty of:

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 I7 Belief Adoption with the instance of E73 Information Object hat a source of or evidence for the I4 Proposition Set that was adopted.

Examples:

- That Francesca Bologna adopted the belief of Tacitus concerning Emperor Nero's whereabouts at the beginning of the Great Fire (I7) *is based on evidence from* Tacitus, Publius Cornelius. *The Annals*. Book 15 [15.6]. (Bologna, 2021)

In First Order Logic:

J7(x,y) ⇒ I7(x)
J7(x,y) ⇒ E73(y)
J7(x,y) ⇒ P16(y)

J13 adopted interpretation (was concluded by)

Domain:

I7 Belief Adoption

Range:

I12 Adopted Belief

Subproperty of:

I1 Argumentation. J2 concluded that (was concluded by): I2 Belief

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I7 Belief Adoption with the instance of I12 Adopted Belief that was established and possibly selected from the interpretation of the source or sources referred to by the property *J14 adopted interpretation of*. This property implies a relation of trust in the reliability of the sources. The actual believed content, i.e., propositions about some past reality that have been adopted from the source, should be documented using the property *J4 that*.

Examples:

- Francesca Bologna adopting the belief of Tacitus concerning Emperor Nero's whereabouts at the beginning of the Great Fire (I7) *adopted interpretation* the belief of Francesca Bologna according to which Nero was at Antium when the Great Fire broke out and did not return to Rome until the fire had approached his hous (I12) (Bologna, 2021)

In First Order Logic:

J13(x,y) ⇒ I7(x)
J13(x,y) ⇒ I12(y)

J13(x,y) ⇒J2(x,y)
J13(x,y) ⇐ (∃uvw) [E73(u)∧ J7(x,z) ∧ I13(v) ∧ J15(x,y) ∧ I4(w) ∧ J4(y,w) ∧ J17(u,y) ∧ J16(v,w)]

J14 adopted interpretation of (has adopted interpretation)

Domain:

I12 Adopted Belief

Range:

E73 Information Object

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I12 Adopted Belief with a source or sources of interpretation from which the belief was established and possibly selected. In some cases of scholarly arguments, multiple source referring to a common topic may have been interpreted in order to form a particular belief about the topic referred to.

Examples:

- Francesca Bologna's belief that "Nero was at Antium when the Great Fire broke out and did not return to Rome until the fire approached his house" (I12) *adopted interpretation of* Tacitus, Publius Cornelius. *The Annals*. Book 15 [15.6] (E73). (Bologna 2021)

In First Order Logic:

J14(x,y) ⇒ I12(x)
J14(x,y) ⇒ E73(y)

J15 assumed meaning (was assumed by)

Domain:

I7 Belief Adoption

Range:

I13 Intended Meaning Belief

Subproperty of:

I5 Inference Making. J1 used as premise (was premise for): I2 Belief

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I7 Belief Adoption with an instance of I13 Intended meaning Belief about a meaning believed to be expressed in the source or sources referred to by the property *J14 adopted interpretation of*.

Examples:

- Francesca Bologna adopting the belief of Tacitus concerning Emperor Nero's whereabouts at the beginning of the Great Fire (I7) *assumed meaning* the belief of Francesca Bologna that what Publius Cornelius Tacitus meant was “Nero was at Antium when the Great Fire broke out and did not return to Rome until the fire approached his house” (I13) (Bologna 2021).

In First Order Logic:

J15(x,y) ⇒ I7(x)
J15(x,y) ⇒ J13(y)
J15(x,y) ⇒ J1(x,y)

J16 assumed meaning (is supposed meaning in)

Domain:

I13 Intended Meaning Belief

Range:

I4 Proposition Set

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I13 Intended Meaning Belief with the instance of I4 Proposition Set that represents the meaning assumed by the holder of the belief to have been intended by the respective source. The latter source can be documented with the property *J17 about (has interpretation)*.

Examples:

- Francesca Bologna’s belief that Publius Cornelius Tacitus meant that “Nero was at Antium when the Great Fire broke out and did not return to Rome until the fire approached his house” (I13)
  assumed meaning
  {Nero in July 19, 64 AD (E93 Presence)
  P164 is temporally specified by: July 19, 64 AD (E52 Time-Span)
  P195 was a presence of: Nero Claudius Caeesar Drusus Germanicus (E21 Person)
  P167 was within Antium in 64 AD, Italy (E53 Place)
  P133 is spatiotemporally separated from: The Great Fire of Rome (E5 Event)
  P1 is identified by: incendium magnum Romae (E41 Appellation)
  P4 has timespan: July 19-27, AD (E52 Time-Span)
  P7 took place at: Rome, in 64AD, Italy (E53 Place)
  }I4 (Bologna, 2021).

In First Order Logic:

J16(x,y) ⇒ I13(x)
J16(x,y) ⇒ I4(y)

J17 about (has interpretation)

Domain:

I13 Intended Meaning Belief

Range:

E73 Information Object

Subproperty of:

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I13 Intended Meaning Belief with the instance of E73 Information Object that was a source of or evidence for the interpretation of its intended meaning. If sources are fragmentary about or complementary to a specific topic, more than one source may have been used.

Examples:

- Francesca Bologna's belief that Gauis Suetonius Tranquillus meant that Nero was singing in Rome while it was burning from July 19 in 64 AD *about* the extant book *De Vita Caesarum*, attributed to Gaius Suetonius Tranquillus.

In First Order Logic:

J17(x,y) ⇒ I13(x)
J17(x,y) ⇒ E73(y)

J18 assumed provenance (was assumed by)

Domain:

I7 Belief Adoption

Range:

I14 Provenance Belief

Subproperty of:

I5 Inference Making. J7 used as premise (was premise for): I2 Belief

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I7 Belief Adoption with an instance of I14 Provenance Belief about the source or sources referred to by the property *J14 adopted interpretation of,* which justifies the conviction that the trusted and adopted content of the source, or its copy at hand, is actually identical, or sufficiently close to the assumed original and its context of creation.

Examples:

- Francesca Bologna adopting the belief of Tacitus concerning Emperor Nero's whereabouts at the beginning of the Great Fire (I7) *assumed provenance* her belief about the authenticity of Tacitus, Publius Cornelius. *The Annals*. Book 15 (I14).

In First Order Logic:

J18(x,y) ⇒ I7(x)
J18(x,y) ⇒ I14(y)
J18(x,y) ⇒ J7(x,y)

J19 that (is subject of)

Domain:

I14 Provenance Belief

Range:

I10 Provenance Statement

Subproperty of:

I2 Belief: J4 that (is subject of): I4 Proposition Set

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I14 Provenance Belief with the instance of I10 Provenance Statement that holds an opinion about it.

Examples:

- Francesca Bologna's belief about the authenticity of Tacitus, Publius Cornelius. *The Annals.* Book 15 *that* the copy of Tacitus, Publius Cornelius. *The Annals.* Book 15[15.6] at the hands of Francesca Bologna from the British Museum in 2021 represents a text written by the ancient Roman historian, Publius Cornelius Tacitus.
- Francesca Bologna's belief about the authenticity of Tacitus, Publius Cornelius. *The Annals.* Book 15 *that* the copy of Tacitus, Publius Cornelius. *The Annals.* Book 15[15.6], which she had access to in 2021 and had originated from the British Museum, represents a text written by the ancient Roman historian, Publius Cornelius Tacitus (I10).

In First Order Logic:

J19(x,y) ⇒ I14(x)
J19(x,y) ⇒ I10(y)
J19(x,y) ⇒ J4(x,y)

J20 is about the provenance of (has provenance claim)

Domain:

I10 Provenance Statement

Range:

E70 Thing

Subproperty of:

E89 Propositional Object. P129 is about (is subject of): E1 CRM Entity

Superproperty of:

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

Scope note:
This property associates an instance of I10 Provenance Statement with an instance of E70 Thing, the provenance of which the statement describes.

Examples:
- The statement: “The exemplar of *The Merchant of Venice*, Quarto 1 (1600) owned by The British Library, shelf number BL C.34.k.22 was published in 1600 AD by Thomas Heyes” (I10) *is about the provenance of* the exemplar of *The Merchant of Venice*, Quarto 1 (1600), owned by the British Library, shelf number BL C.34.k.22 (E70).

In First Order Logic:
J20(x,y) ⇒ I10(x)
J20(x,y) ⇒ E70(y)
J20 (x,y) ⇒ P129(x,y)

J21 concluded provenance (was assessed by)

Domain:
I15 Provenance Assessment

Range:
I14 Provenance Belief

Subproperty of:
I1 Argumentation. J2 concluded that (was concluded by): I2 Belief

Superproperty of:

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

Scope note:
This property describes the naming or identification of any real-world item by a name or any other identifier.

This property associates an instance of I15 Provenance Assessment with an instance of I14 Provenance Belief that constitutes the conclusion of the assessment. An instance of I15 Provenance Assessment may conclude more than one instances of I14 Provenance Belief, typically about different objects considered in the same assessment.

Examples:
- The assessment by Ersnt Pernicka et al. about the provenance of the Nebra Sky Disc (I15) *concluded that* Ernst Pernicka et al. believe that the Nebra Sky Disc dates to the Early Bronze Age (Pernicka et al. 2020)

In First Order Logic:
J21(x,y) ⇒ I15(x)
J21(x,y) ⇒ I14(y)

J21 (x,y) ⇒ J2(x,y)

J22 interpreted meaning of (was interpreted by)

Domain:

I16 Meaning Comprehension

Range:

E73 Information Object

Subproperty of:

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 I16 Meaning Comprehension with the instance of E73 Information Object that was the source of or evidence for the interpretation of its intended meaning. If sources are fragmentary about or complementary to a specific topic, more than one source may have been used.

Examples:

- My understanding of the statements about Emperor Nero's whereabouts in Rome while it was burning from July 1 in 64 AD (I16) interpreted meaning of the extant *book De Vita Caesarum* by Gaius Suetonius Tranquillus.

In First Order Logic:

J22(x,y) ⇒ I16(x)
J22(x,y) ⇒ E73 (y)
J22 (x,y) ⇒ P16(x,y)

J23 interpreted meaning as (was interpretation by)

Domain:

I16 Meaning Comprehension

Range:

I13 Intended Meaning Belief

Subproperty of:

I1 Argumentation. J2 concluded that (was concluded by): I2 Belief

Superproperty of:

Quantification:

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

Scope note:

This property associates an instance of I16 Meaning Comprehension with the instance of I13 Intended Meaning Belief that was the result of the interpretation of the intended meaning of the analysed source(s).

Examples:

- My understanding of the statements about Emperor Nero's whereabouts in Rome while it was burning from July 19 in 64 AD (I16) *interpreted meaning as* believing that it meant Nero was singing in Rome while it was burning from July 19 in 64 AD (I13).

In First Order Logic:

J23(x,y) ⇒ I16(x)
J23(x,y) ⇒ I13 (y)
J23(x,y) ⇒ J2(x,y)

Works Cited

Bologna, F. (2021) ‘Who was Nero?’, *The British Museum Blog*, 22 April. Available at: https://www.britishmuseum.org/blog/who-was-nero (Accessed: 10 April 2023).

Doerr, M., Kritsotaki, A., & Boutsika, A. (2011). Factual argumentation - a core model for assertions making. *Journal on Computing and Cultural Heritage (JOCCH)* , *3*(3), 34, New York, NY, USA : ACM

Doerr, M., Kritsotaki, A., Rousakis, Y., Hiebel, G., Theodoridou, M. et al (2019) CRMsci, version 1.2.7

Bekiari, C., Doerr, M., Le Bœuf, P., Pat Riva, P. et al (2019). LRMoo: object-oriented definition and mapping from IFLA LRM version 0.5

Hodder, I. (1999) The Archaeological Process: An Introduction. Oxford: Blackwell.

Gangemi. A. & Mika P. (2003). Understanding the semantic web through descriptions and situations. In *Proceedings of DOA/CoopIS/ODBASE 2003 Confederated International Conferences DOA, CoopIS and ODBASE, LNCS*. Springer, 2003.

Giorgi, R., Dei, L., Schettino, C., & Baglioni, P. (2002). A NEW METHOD FOR PAPER DEACIDIFICATION BASED ON CALCIUM HYDROXIDE DISPERSED IN NONAQUEOUS MEDIA, Studies in Conservation, 47:sup3, 69-73, DOI: 10.1179/sic.2002.47.s3.014

Pernicka, E. et al. (2020) ‘Why the Nebra Sky Disc Dates to the Early Bronze Age. An overview of the Interdisciplinary Results’, Journal on the Archaeology of Europe, 104, pp. 89–122. doi:10.1553/archaeologia104s89

Szirmai, J.A. (1999). *The archaeology of medieval bookbinding.* Aldershot, Hants.; Bookfield, Vt.: Ashgate.

Wikipedia (2023) ‘The Twelve Caesars’, *Wikipedia; The Free Encyclopedia*. Available at: https://en.wikipedia.org/wiki/The_Twelve_Caesars#External_links (Accessed: 19 September 2023).