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Information technology — Top-level ontologies (TLO) —

Part 1: Requirements

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Foreword

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Introduction

This document was developed in response to the demand from many quarters for ontology-based solutions to the problem of semantic interoperability across networks of information systems. The demand arises particularly from large organizations and consortia of organizations in areas such as bioinformatics, healthcare, the manufacturing industry and military and government administration, where independently created information systems need to exchange data in such a way that meaning is preserved.

An ontology is on the one hand an artefact for human use, built out of terms and relations expressed using natural language. On the other hand, it is an artefact for use by computers, which requires that these terms and relations are captured in a formal language that is machine readable and has well-defined (typically, model-theoretic) semantics. Multiple languages have been developed for the purposes of ontology formalization, of which Common Logic (CL) and the Web Ontology Language (OWL) – specifically OWL 2 with direct semantics – are normatively referenced in this document.

An ontology can help to achieve sharing of meaning because its terms are associated with formal definitions specifying their meanings in a way that can be processed computationally. If an ontology can be shared across participating organizations, then data can be exchanged in such a way that meaning is preserved if the data can be associated with corresponding shared ontology terms.

CL and OWL 2 serve different ends. CL is a logical framework with the full expressivity of first-order logic (FOL), the unifying framework for all semantic web applications. Formalization in a language with the expressivity of FOL is required for the purposes of this document since weaker expressivity would not allow the ontology to capture in a formal way the implications of axioms in areas such as mereology and theories of location and change.

Formalization in a language like OWL 2 is needed, even though it is less expressive than CL, since it is decidable and this means that it can be used effectively by computer systems for purposes of logical reasoning and ontology quality assurance.

Where heterogeneous bodies of data need to be exchanged or manipulated, some have adopted approaches that involve the creation of a suite of ontologies incorporating a distinction of levels, with a single very general ontology at the top, governing one or more specific ontology modules at lower levels (Annex A provides examples). This document addresses the need that arises for those communities that have adopted such multi-level approaches. Specifically, its purpose is to specify what is required of a top-level ontology if it is to serve the needs of those building or re-engineering ontologies or other legacy systems at lower levels in a way that will support semantic interoperability among them.

To be fit for purpose, a top-level ontology needs to have appropriate content that is well documented and be available in machine-readable forms providing support for computational reasoning. This document specifies these requirements in terms of coverage, documentation and representation.

Information technology — Top-level ontologies (TLO) —

Part 1: Requirements

1 Scope

This document specifies required characteristics of a domain-neutral top-level ontology (TLO) that can be used in tandem with domain ontologies at lower levels to support data exchange, retrieval, discovery, integration and analysis.

If an ontology is to provide the overarching ontology content that will promote interoperability of domain ontologies and thereby support the design and use of purpose-built ontology suites, then it needs to satisfy certain requirements. This document specifies these requirements. It also supports a variety of other goals related to the achievement of semantic interoperability, for example, as concerns legacy ontologies developed using heterogeneous upper-level categories, where a coherently designed TLO can provide a target for coordinated re-engineering.

This document specifies the characteristics an ontology needs to possess to support the goals of exchange, retrieval, discovery, integration and analysis of data by computer systems.

The following are within the scope of this document

— Specification of the requirements an ontology needs to satisfy if it is to serve as a top-level hub ontology.

— Specification of the relations between a top-level ontology and domain ontologies.

— Specification of the role played by the terms in a top-level ontology in the formulation of definitions and axioms in ontologies at lower levels.

The following are outside the scope of this document:

— Specification of ontology languages, including the languages OWL 2 and CL, used in ontology development with standard model-theoretic semantics.

— Specification of methods for reasoning with ontologies.

— Specification of translators between notations of ontologies developed in different ontology languages.

— Specification of rules governing the use of IRIs as permanent identifiers for ontology terms.

— Specification of the principles of ontology maintenance and versioning.

— Specification of how ontologies can be used in the tagging or annotation of data.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 24707, *Information technology — Common Logic (CL) — A framework for a family of logic-based languages*

WORLD WIDE WEB CONSORTIUM *W3C Recommendation — OWL 2 Web Ontology Language Document Overview* (Second Edition), https://www.w3.org/TR/2012/REC-owl2-overview-20121211/

WORLD WIDE WEB CONSORTIUM *W3C Recommendation — OWL 2 Web Ontology Language Direct Semantics,* https://www.w3.org/TR/owl2-direct-semantics/

WORLD WIDE WEB CONSORTIUM *W3C Recommendation — OWL 2 Web Ontology Language Structural Specification and Functional-Style Syntax* (Second Edition), http://www.w3.org/TR/2012/REC-owl2-syntax-20121211/

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

NOTE The following terms and definitions are not intended as a substitute for existing technical vocabularies used in ontology development and maintenance, for example, as defined by the W3C. To reduce the possibility of confusion, expressions used in describing a W3C recommended usage are capitalized.

3.1
entity
object
item that is perceivable or conceivable

Note 1 to entry: The terms 'entity' and 'object' are catch-all terms analogous to 'something'. In terminology circles 'object' is commonly used in this way. In ontology circles, 'entity' and 'thing' are commonly used. See B.3.3.

[SOURCE: ISO 1087-1:2000]

3.2
class
general *entity* (3.1)

Note 1 to entry: In some ontology communities, all general entities are referred to as classes. In other ontology communities, a distinction is drawn between classes as the extensions of general entities (for example, as sets of instances) and the general entities themselves, sometimes referred to as 'types', 'kinds', or 'universals'. The expression 'class or type' is used in this document in order to remain neutral regarding these different usages.

3.3
particular
individual *entity* (3.1)

Note 1 to entry: In contrast to classes or types, particulars are not exemplified or instantiated by further entities.

3.4
relation
way in which *entities* (3.1) are related

Note 1 to entry: Relations can hold between particulars (this leg *is part of* this lion); or between classes or types (mammal *is a subclass of* organism); or between particulars and classes or types (this lion *is an instance of* mammal). On some views, identity is treated as a relation connecting one entity to itself.

Note 2 to entry: On the difference between 'relation' and 'relational expression' see 3.6, Note 1 to entry.

Note 3 to entry: 'Relation' is a primitive term. See 4.1.1, NOTE 1.

3.5
expression
word or group of words or corresponding symbols that can be used in making an assertion

Note 1 to entry: Expressions are divided into natural language expressions and expressions in a formal language.

3.6
relational expression
expression (3.5) used to assert that a *relation* (3.4) obtains

EXAMPLE 'is a' (also known as 'subtype' or 'subclass'), 'part of', 'member of', 'instantiates' 'later than', 'brother of', 'temperature of'.

Note 1 to entry: The term 'relational expression' is introduced in order to remove any confusion that can arise if a person uses 'relation' to refer to the real-world link or bond between entities (as in 3.4), while another person uses 'relation' to refer to the linguistic representation of this real-world link or bond.

Note 2 to entry: In OWL 2, relational expressions are referred to as Properties. 'Expression' is used to connote logical composition: a Class Name in OWL 2 is logically simple, a Class Expression is logically complex. In FOL, 'n-ary predicate' is often used as a synonym of 'relational expression'.

3.7
term
expression (3.5) that refers to some *class* (3.2) or to some *particular* (3.3)

Note 1 to entry: An ontology will typically contain a unique 'preferred term' for the entities within its coverage domain. Preferred terms may then be supplemented with other terms recognized by the ontology as synonyms of the preferred terms.

3.8
definition
concise statement of the meaning of an *expression* (3.5)

Note 1 to entry: For the purposes of this document, definitions can be of two sorts: (1) those formulated using a natural language such as English, supplemented where necessary by technical terms or codes used in some specialist domain; (2) those formulated using a computer-interpretable language such as OWL 2 or CL.

3.9
axiom
statement that is taken to be true, to serve as a premise for further reasoning

Note 1 to entry: Axioms may be formulated as natural language sentences or as formulae in a formal language. In the OWL community, 'Axiom' is used to refer to statements that say what is true in the domain that are 'basic' in the sense that they are not inferred from other statements.

3.10
formal language
language that is machine readable and has well-defined semantics

Note 1 to entry: Well-defined semantics will typically be model-theoretic semantics.

3.11
formal theory
collection of *definitions* (3.8) and *axioms* (3.9) expressed in a *formal language* (3.10)

Note 1 to entry: In some formal theories, definitions are expressed by means of axioms.

3.12
axiomatization
result of expressing a body of knowledge or information as a *formal theory* (3.11)

3.13
logical interpretability
ability to derive each and every *axiom* (3.9) of one *formal theory* (3.11) from another

Note 1 to entry: One formal theory is logically interpretable in a second formal theory if the language of the first can be translated into the language of the second so that the translation of every axiom in the first is derivable from the second.

3.14
ontology
collection of *terms* (3.7), *relational expressions* (3.6) and associated natural-language *definitions* (3.8) together with one or more *formal theories* (3.11) designed to capture the intended interpretations of these definitions

Note 1 to entry: Background materials on the sources, rationale and interpretation of this definition are provided in Annex B.

3.15
signature
set of non-logical symbols of a *formal language* (3.10) or *formal theory* (3.11)

Note 1 to entry: The signature of an ontology consists of a set of *terms* (3.7) and *relational expressions* (3.6).

3.16
knowledge base
combination of an *ontology* (3.14) with a collection of data which *terms* (3.7) in the ontology have been used to describe, classify or connect.

3.17
domain
collection of *entities* (3.1) of interest to a certain community or discipline

EXAMPLE The domain of agriculture, the domain of cell biology, the domain of aircraft maintenance, the domain of philately.

Note 1 to entry: ‘Entities of interest’ can include both particulars and classes or types. The definition is to be interpreted as meaning that a domain is a collection of entities that is narrow in scope. Thus, there is no universal domain, to which everything would belong. Compare with ISO/IEC 2382[21], which defines ‘domain model’ in the context of artificial intelligence as: model of a specific field of knowledge or expertise.

3.18
domain ontology
ontology (3.14) whose *terms* (3.7) represent *classes* (3.2) or *types* and, optionally, certain *particulars* (3.3) (called ‘distinguished individuals’) in some *domain* (3.17)

3.19
category
general *class* (3.2) or type that is shared across many different *domains* (3.17) and is represented by a domain-neutral *term* (3.7)

EXAMPLE Process, attribute, event, region, information entity.

3.20
top-level ontology
TLO
ontology (3.14) that is created to represent the *categories* (3.19) that are shared across a maximally broad range of *domains* (3.17)

Note 1 to entry: Top-level ontologies are ‘reference ontologies’ in the sense of ISO/IEC 19763-3[5], A top-level ontology is sometimes referred to as a ‘formal ontology’, ‘foundational ontology’, ‘upper level ontology’, or ‘domain-neutral ontology’.

3.21
ontology suite
collection of *ontologies* (3.14) developed in such a way as to be mutually consistent and non-redundant

Note 1 to entry: See Annex A.

3.22
ontology reuse
importing an *ontology* (3.14), or part of an ontology, into a second ontology in such a way as to preserve the meaning of the imported content

EXAMPLE Terms from a tool ontology are reused in a power tool ontology; the latter is a specialization of the former.

Note 1 to entry: Terms from the existing ontology will typically be reused in the new ontology and appear together with the newly created terms.

3.23
ontology conformance
relation (3.4) between two *ontologies* (3.14) when one consistently extends the other

EXAMPLE A power tool ontology stands in the *relation* of *ontological conformance* to a tool ontology if the former is a consistent ontology that results from adding new content (terms, definitions, axioms) to the latter.

Note 1 to entry: 'Extension' means semantically that any element in a model of the extending ontology which satisfies the conditions for being an instance of a class in the starting ontology must be an instance of that class in the extending ontology.

Note 2 to entry: This is a narrowly defined usage of 'conformance' that is intended to be used only in contexts in which relations between ontologies are at issue. Where conformance in the sense of *fulfilment of a requirement or satisfaction of a criterion* is intended in this document, the term 'conformity' is used.

4 Requirements for a top-level ontology

4.1 TLO as textual artefact

4.1.1 Overview

A TLO shall include a textual artefact represented by a natural language document providing: (1) a list of domain-neutral terms and relational expressions, incorporating identification of primitive terms, and (2) definitions of the meanings of the terms and relational expressions listed. Natural-language definitions may incorporate semi-formal elements if these are needed for readability.

NOTE 1 In the case of primitive terms, definitions can take the form of elucidations of meaning supplemented by examples of use.

EXAMPLE An example of a definition with semi-formal elements is:

transitivity =def. relation R is transitive if whenever *a* stands in R to *b* and *b* stands in R to *c* it follows that *a* stands in R to *c.*

Given the nature of a TLO, a portion of its terms and relational expressions will be so basic in their meaning that there will be no logically simpler, and thus more easily intelligible, expressions on the basis of which they can be defined in a non-circular way. Ontology terms and relational expressions for which this is the case are called 'primitives', and they have definitions in the sense of 3.8, but these are circular or are mere paraphrases.

A TLO shall specify which of its terms and relational expressions are primitive in this sense. For all other terms and relational expressions in the TLO, definitions shall be provided which satisfy the conditions that:

a) they are non-circular;

b) they form a consistent set;

c) they are concise.

NOTE 2 Concise signifies that the definition contains no redundant elements (for example, lists of examples, explanations of usage, and so on).

These requirements apply both to the natural language definitions and also to the definitions provided in the OWL 2 and CL axiomatizations referenced in 4.2 and 4.3.

Non-circularity excludes not only immediate circularity (where the defined term or a term with equivalent meaning is used in the definition) but also mediated circularity (for example, where a term is used in the definition of a second term, which is itself used in the definition of the first term). To ensure non-circularity it is recommended that definitions are formulated as statements of singly necessary and jointly sufficient conditions for the correct application of the defined term.

EXAMPLE Triangle = def. closed figure that lies in a plane and consists of exactly three straight lines.

Consistency of the collection of natural language definitions is shown through the development of an axiomatization that is proven consistent, as described in 4.2 and 4.3.

NOTE 3 Consistency, non-circularity and conciseness of definitions are features that distinguish ontologies from traditional dictionaries and other lexical resources.

4.1.2 Relations between textual artefact and axiomatizations of the TLO

The terms and relational expressions in the textual artefact shall be converted into symbols in the axiomatizations. These symbols together form the signature of the resultant logical theory. They may incorporate textual strings.

EXAMPLE The text string 'is a' is converted into the symbol 'is_a'.

Terms and relational expressions in the textual artefact should have counterparts in the OWL 2 axiomatization wherever this is feasible, given the expressivity of OWL.

Each definition in the textual artefact whose content is expressible in OWL 2 shall correspond in the OWL 2 axiomatization to a group of one or more axioms with a corresponding logical content.

All terms in the textual artefact shall correspond to terms in the CL axiomatization.

All definitions of non-primitive terms in the textual artefact shall correspond to axioms in the CL formalization.

4.2 Axiomatization in the Web Ontology Language (OWL 2 with direct semantics)

4.2.1 General

The TLO shall be made available via at least one machine-readable axiomatization in OWL 2 with the direct semantics or in some description logic that is designated by W3C as a successor of OWL 2. The signature of the OWL axiomatization shall be identical, modulo the conversion from strings into symbols and modulo the conversion of ternary into binary relational expressions, to the set of natural language terms and relational expressions of the TLO as specified under 4.1. The axioms should represent the content of the natural language definitions described in 4.1 to the extent that this is possible given the expressivity of OWL 2. The axiomatization shall satisfy the conformity criteria in *W3C Recommendation — OWL 2 Web Ontology Language Direct Semantics*. The axiomatization shall be proven consistent using standard OWL reasoners. The axiomatization shall be interpretable in the CL axiomatization described in 4.3.

In the OWL 2 axiomatization, terms and relational expressions are replaced by IRIs[1] used in accordance with the rules in the *W3C Recommendation — OWL Web Ontology Language Guide*[2].

4.2.2 Alternative OWL 2 Axiomatization

In some cases, in order to compensate for the restrictions on axiom closure in an OWL 2 ontology, a TLO may be provided with two or more OWL 2 axiomatizations, neither of which is logically interpretable in the other (*W3C Recommendation — OWL 2 Web Ontology Language Structural Specification and Functional-Style Syntax)*. Each such axiomatization shall however be logically interpretable in the CL axiomatization and a specification shall be provided of how such OWL 2 axiomatizations relate to each other and why each is needed.

NOTE 1 In the simplest case, the axiomatizations form a set linearly ordered in terms of theory strength, where theory A is stronger than theory B when B is logically interpretable in A, but A is not logically interpretable in B. Theory B is logically interpretable in theory A if, and only if, the language of B can be translated into the language of A so that every theorem of B is derivable in A. An ontology developed in OWL 2 is always logically interpretable in CL, but not vice versa.

NOTE 2 To define 'axiom closure', the import closure I(O) of an ontology O is first defined as the set containing O and all the ontologies that O imports. The axiom closure of O is then the smallest set that contains all the axioms in I(O) when the anonymous individuals from different ontologies in I(O) are treated as being different (*W3C Recommendation — OWL 2 Web Ontology Language Structural Specification and Functional-Style Syntax*).

4.3 Axiomatization in a CL-conforming language

The TLO shall be made available via an axiomatization in a language conforming to ISO/IEC 24707.

NOTE CL, a logical framework standardized for the purpose of facilitating exchange and transmission of knowledge in computer-based systems, is the standard ontology development language defined in ISO/IEC 24707. Many of the principles underlying a TLO – for example, regarding change, mereology, and temporal and spatial location – cannot be adequately expressed using OWL but require the expressivity of first-order logic provided by CL. CL is a family of formal languages with a common descriptive semantics. Since CL circumvents differences in formal language syntax by focusing on a shared semantics, translations between distinct formal languages are easier to automate.

EXAMPLES Languages conforming to CL specified in ISO/IEC 24707 are the Common Logic Interchange Format (CLIF), the Conceptual Graph Interchange Format (CGIF), and the XML-based notation for Common Logic (XCL). For details of how languages traditionally used in first-order logic (FOL) can also conform to ISO/IEC 24707, see Reference [7].

The signature of the CL axiomatization shall be identical, modulo the conversion from strings into symbols, to the set of natural language terms and relational expressions of the ontology as specified in 4.1. The axiomatization shall extend the OWL 2 DL axiomatization described in 4.3 in the sense that its models shall also satisfy the CL translation of the OWL 2 axiomatization. The axiomatization shall be proven consistent using standard automated theorem provers. The axiomatization shall be explicitly modularized.

4.4 Supplementary documentation

4.4.1 Overview

Supplementary documentation shall be made publicly available:

— specifying how the ontology is used or is intended to be used;

— specifying how it is shown that the OWL axiomatization specified in 4.2 is logically derivable from the CL axiomatization specified in 4.3;

- demonstrating the breadth of coverage of the ontology by addressing the questions listed in 4.4.6;
- documenting policies for ontology management.

4.4.2 Documentation of the purpose of the TLO

The actual or envisaged purpose of the TLO shall be described in detail.

EXAMPLES Uses of a TLO as a framework:

a. for the development of domain ontologies or domain ontology suites (in Annex A);

b. for the development of knowledge bases drawing on data from multiple domains;

c. for the re-engineering of existing ('legacy') domain ontologies and similar information artefacts with the purpose of advancing interoperability or to promote clarity of definitions;

d. for ontology support for systems integration initiatives (involving both humans and machines);

e. for high-level structuring of cross-domain lexical resources such as WordNet (for example for purposes of disambiguation of polysemous expressions);

f. to regiment the terminological content of a scientific theory;

g. to support web-based cataloguing of large collections for example by museums or media organizations.

4.4.3 Documentation concerning demonstration of conformance of a domain ontology to the TLO

Where, as in 4.4.2, EXAMPLES a-c, the TLO is used in conjunction with external domain ontology resources in ways which require conformance of these resources to the TLO in accordance with definition 3.23, documentation is required concerning (a) the mechanisms used to achieve such conformance, (b) the methods used to demonstrate conformance. Recommended methods are outlined in Annex D.

4.4.4 Documentation concerning consistency of the CL axiomatization

Documentation shall be provided which provides an interpretation that demonstrates that the CL axiomatization is consistent, with instructions on how to verify satisfaction. This documentation shall include a specification of the model used to prove consistency and an account of how the TLO is modularized.

NOTE A set of CL axioms is consistent if the set of formulae derivable from the axioms using the standard rules of inference does not contain a contradiction. Consistency can be proved either semantically or syntactically. A semantic proof shows that the set of axioms has an interpretation (also called a model) in which all axioms are satisfied. A syntactic proof can be either direct or indirect. The former proves directly that there is no formula such that both it and its negation are derivable from the axioms. The latter proves consistency by using theorem provers to show that a set of axioms is logically interpretable in a theory that has already been proved consistent. This technique is used for theories that have no finite models.

4.4.5 Documentation concerning the relation between OWL and CL axiomatizations

Documentation shall be provided specifying how it is shown that the OWL 2 axiomatization specified in 4.2 is logically derivable from the CL axiomatization specified in 4.3. This documentation is required in order to establish that the two axiomatizations can be accepted as axiomatizations of one and the same ontology.

EXAMPLE It is shown that OWL 2 axiomatization A is logically interpretable in CL axiomatization B through the following steps: 1. an automatic syntactic translator is used to convert A into CL(A) with CL-conforming syntax; 2. translation definitions which bridge the signature of B to that of CL(A) are added to B, yielding the result TR(B); 3. an automated theorem prover is used to show that the translation of each axiom of CL(A) is entailed by TR(B).

CL allows the development of ontologies stronger than those developed in OWL 2, in the sense that an OWL 2 axiomatization is always logically interpretable in a CL axiomatization but not vice versa. Given the differences in expressivity as between OWL 2 and CL, it may be necessary to use terms and relational expressions in the OWL 2 axiomatization that are not present in the CL axiomatization and vice versa. To show logical interpretability of the former in the latter it would then be necessary to add the corresponding expressions and their definitions to the CL axiomatization. Such addition shall be a conservative extension of the CL axiomatization, which means that any theorem formulable in the extended ontology using only the old signature is already provable without the extension.

4.4.6 Documentation demonstrating breadth of coverage

4.4.6.1 Overview

The ontology documentation shall provide answers to the questions listed in subclauses 4.4.6.2 through 4.4.6.16. These answers shall document how the TLO would be used in managing data of the types addressed in each subclause. (Annex C provides examples of such documentation.)

In some TLOs data about entities of given classes or types would be managed by using terms included in the ontology representing those classes or types. Where a TLO does not include classes or types that cover one or more of the areas identified, it shall be documented how it will address corresponding data, for example, by specifying an additional ontology whose relation to the TLO is documented.

NOTE The rationale for requiring breadth of coverage in a TLO is as follows. When an ontology-based approach is adopted, for example, by a large organization in order to promote interoperability of the data systems within its constituent sub-organizations, the ontologies in question will be required to deal with an evolving collection of different sorts of data. These will include:

— data that is spatially and temporally referenced;

— data about entities that change over time;

— data that result from assays along multiple qualitative and quantitative dimensions;

— data reflecting mereological and other relations between such entities, including relations between entities and the material of which they are composed;

— data about data artefacts themselves (for example about designs, plans, requirements specifications).

If it is to have a high likelihood of being able to serve reliably as an over-arching framework for the management of data in such circumstances – even when new sorts of data are being brought on stream – then a TLO requires a maximal breadth of coverage in the set of terms it includes. Similarly, a TLO should include relational expressions that enable representation of a broad range of relations among entities in its chosen categories. Various candidate TLOs have made different – and sometimes incompatible – choices concerning these categories and relations. To show conformity to this document, these choices shall be documented in a way that will justify the claim that the ontology has a sufficiently broad coverage of categories and associated relations to satisfy the requirements of a TLO as defined by this document.

4.4.6.2 Space and time

How does the ontology deal with time, space and spacetime?

— Does the ontology recognize entities which persist in time?

— How does the ontology deal with entities which occur in time?

— Does the ontology recognize entities which are extended in both space and time?

— How does the ontology deal with spatial, temporal and spatiotemporal regions?

4.4.6.3 Actuality and possibility

How does the ontology deal with what could happen or what could be the case, rather than what is the case or has happened?

— How does the ontology deal with possibility?

— Does the ontology support both possible and actual entities?

— Does the ontology have a treatment of dispositions or tendencies?

— Does the ontology have a way of dealing with merely possible or potential entities as might be described in unrealized plans or designs?

4.4.6.4 Classes and types

How does the ontology deal with issues of classification?

— Does classification reflect the existence of certain relations of similarity between certain entities, or do classes or types exist as general entities in addition to particular instances?

— Are classes of classes allowed?

— Does the ontology distinguish between types and the classes of their instances?

— Are classes or types instantiated by the same particulars identical?

4.4.6.5 Time and change

How does the ontology deal with time and change?

— How does the ontology deal with the distinction between past, present and future entities?

— How does the ontology deal with identity and change of material objects over time?

— How does the ontology deal with location, and with change of location?

— Does the ontology allow for more than one material object to occupy exactly the same spatial location at the same time?

— How does the ontology deal with changeable properties, such as being a student?

— Does the ontology recognize a distinction between classes or types that apply necessarily to a particular for the whole of its existence, and classes or types that apply only temporarily?

EXAMPLES *Mammal* is an example of a class or type that applies to a particular for the whole of its existence. An organism is an example of an entity that can undergo change over time, such as by losing hair, without changing identity.

4.4.6.6 Parts, wholes, unity and boundaries

How does the ontology deal with relations of parthood?

— If one entity is part of a second entity, and this entity part of a third entity, does it follow that the first entity is also part of the third entity?

— If one entity is part of but not identical to a second entity, must there be a third entity which makes up the difference?

— How does the ontology deal with wholes formed through the summation of parts?

— How does the ontology deal with continuity where a material object has parts between which there is no natural boundary?

— How does it deal with the factor of unity, which obtains where the parts of a whole are joined together in a way that distinguishes it from a sum?

EXAMPLES Unity is manifested by organisms or planets through the relation of direct or indirect physical connectedness; unity is manifested by solar systems and galaxies through relations of gravity that are above certain thresholds. Unity is manifested by a married couple through the relation of married to, and by a group of siblings through the relation sibling of.

NOTE A whole manifesting the factor of unity can be defined as being such that all its parts are related to each other, and only to each other, by a single distinguished relation.

4.4.6.7 Space and place

— How does the ontology deal with places and locations?

— How does the ontology deal with holes, conduits, cavities, a vacuum?

— How does the ontology deal with shape?

4.4.6.8 Scale and granularity

How does the ontology deal with scale, granularity and levels of reality?

— Does the ontology treat the material world as being made up of entities at distinguished levels?

EXAMPLES Atoms, molecules, cells, organisms, planets and galaxies are examples of entities at distinguished levels of reality.

4.4.6.9 Qualities and other attributes

How does the ontology deal with qualities and other attributes?

NOTE ‘Attribute’ here is meant to include what are sometimes referred to as properties, features or characteristics.

— How do attributes relate to the entities that have or bear them?

— Does the ontology distinguish between attributes and values?

— Does the ontology recognize attributes of attributes?

EXAMPLES Quantitative and qualitative are examples of attributes of attributes.

4.4.6.10 Quantities and mathematical entities

How does the ontology deal with quantitative data and with mathematical data and theories?

— How does the ontology deal with units of measure?

— How are those attributes which are represented using qualitative terms such as ‘hot’ or ‘elevated temperature’ related to attributes represented using quantity expressions such as ‘63 °C’?

4.4.6.11 Processes and events

How does the ontology deal with processes?

— Are processes identical to changes?

— What kinds of processes exist?

— Does the ontology allow attributes of processes?

— Does the ontology distinguish between processes and states?

— Does the ontology recognize instantaneous processes?

4.4.6.12 Constitution

— How does the ontology deal with the relation – sometimes referred to as a relation of ‘constitution’ – between material entities and the material of which, at any given time, they are made?

— How does the ontology deal with the relation between, for example, minds and brains, persons and organisms, or between organizations and the totality of their members?

— Is there an analogue of the relation of constitution holding between processes, or between non-material entities of other sorts?

4.4.6.13 Causality

— How does the ontology deal with causality?

4.4.6.14 Information and reference

— How does the ontology deal with information entities?

EXAMPLES Databases, symbols, text documents, emails, video files, a speech.

— Does the ontology incorporate a relation between an information entity and what the information entity is about?

— If yes, how does the ontology deal with cases where there is no actual entity which a given information entity is about? Does the ontology deal with cases of this sort by recognizing possible worlds?

EXAMPLE Cases of aboutness where there is no corresponding actual entity may arise where plans for the future are being made.

4.4.6.15 Artefacts and socially constructed entities

— How does the ontology deal with artefacts?

EXAMPLE Engineered items.

— How does the ontology deal with entities commonly viewed as socially constructed, such as money?

— How does the ontology deal with entities such as laws, agreements, duties or permissions?

4.4.6.16 Mental entities; imagined entities; fiction; mythology; religion

— How does the ontology deal with mental entities?

EXAMPLES Minds, thoughts, decisions, memories, images.

— How does the ontology deal with imagined entities?

— How does the ontology deal with entities or data in the realm of mythology?

— How does the ontology deal with entities or data in the realm of fiction?

— How does the ontology deal with entities or data in the realm of religion?

4.4.7 Domain neutrality

4.4.7.1 General

The signature of the TLO shall contain no terms or relational expressions that are used exclusively in one or in a restricted group of domains.

EXAMPLE 1 Nuclear physics is a domain whose terms are not used widely in other domains.

NOTE There is agreement among developers of TLOs that expressions such as 'object', 'process', 'set', 'attribute', 'fact', and 'part_of' are domain neutral, while expressions such as 'war', 'neutrino', 'cervix', 'uncle of' and 'maximum allowable working temperature' are domain specific. Between these two groupings, however, is a grey area of expressions accepted as domain neutral in some TLOs but not in others.

EXAMPLE 2 'Information', 'meaning', 'shape', 'person', 'social object', 'purpose' are expressions that might or might not be included in a TLO.

4.4.7.2 Existence as a self-standing ontology

For the TLO to have the property of domain neutrality means that it shall exist as a self-standing ontology rather than as a collection of top-level terms and relational expressions embedded in a larger ontology detailing one or more particular domains.

NOTE The rationale for this requirement turns on the need (1) to ensure a division of authority and of responsibility for maintenance of the TLO and of the domain ontologies which it supports and (2) to secure the ability of a TLO to serve purposes such as cross-disciplinary or cross-enterprise interoperability among these domain ontologies in a way that minimizes the possibility of forking.

EXAMPLE An ontology O is proposed to serve as a TLO but its TLO elements are not self-standing because O contains also elements from multiple domains. O is then adopted by scientists working in some domain D. Independently of this, an alternative ontological treatment of D is developed by domain experts. There is then no simple way to associate this alternative treatment of D with the TLO in O. To replace the existing D-related content in O with the new treatment will imply changes being made in O by domain experts rather than TLO experts, introducing conflicts between different sorts of expertise and governance. These conflicts, and the ontology forking to which they could lead, are avoided if the TLO elements of O are created as a self-standing module.

4.4.8 Ontology management

Documentation shall be made available specifying:

— ontology licence (code and content);

— ontology governance;

— policy governing interaction with users;

— policy for making and approving changes in the ontology;

— ontology versioning policy;

— policy for creation and maintenance of identifiers and IRIs.

5 Conformity

5.1 Overview

An ontology claiming conformance to this document shall make available two sorts of documentation, as specified in 5.2 and 5.3.

5.2 Ontology documentation

— A natural language document satisfying the requirement in 4.1, designed to support use and maintenance of the ontology by human beings,

— An axiomatization of the ontology in OWL 2 with direct semantics satisfying the requirement in 4.2, designed to support computational reasoning,

— An axiomatization of the ontology in a CL-conforming language satisfying the requirement in 4.3.

5.3 Supplementary documentation

— A set of supplementary documents satisfying the requirements in 4.4.4 through 4.4.8.

Annex A
(informative)

Examples of ontology suites

A primary focus of this document is to specify the requirements ontologies shall satisfy if they are to support the design and use of purpose-built suites of ontologies by providing the overarching ontology content which the ontologies in the suite will be required to share in common in order to promote interoperability. Table A.1 lists examples of ontology suites proposed by different communities since 1998, ordered by year of first archival publication. Each such suite represents an attempt by developers of multiple ontologies covering different but related domains of entities to ensure mutual consistency between the ontologies being developed. A common method to achieve such coordination involves the application of a hub-and-spokes strategy, resting on use of a top-level ontology as defined in this document, together with successive layers of spokes comprising domain ontologies built out of terms defined as specializations of terms contained in this top-level hub.

Table A.1 — Examples of ontology suites

Ontology suite	Domain	Year	IRI of archived publication	Hub
Toronto Virtual Enterprise (TOVE)	enterprise modeling	1998	https://www.aaai.org/ojs/index.php/aimagazine/article/view/1399	Yes
Gene Ontology (GO)	attributes of gene products	2000	https://www.nature.com/ng/journal/v25/n1/abs/ng0500_25.html	No
Gramene: Trait and Gene Ontologies for Rice	plant science	2002	http://onlinelibrary.wiley.com/doi/10.1002/cfg.156/full	Yes
Semantic Web for Earth and Environmental Terminology (SWEET)	earth and environmental sciences	2004	https://doi.org/10.1016/j.cageo.2004.12.004	No
Legal Informatics Ontologies (LRI-Core)	legal informatics	2004	https://link.springer.com/article/10.1007/s10506-006-0002-1	Yes
Open Biomedical Ontologies (OBO) Foundry	life sciences	2005	https://www.nature.com/nbt/journal/v25/n11/full/nbt1346.html	Yes
Performance Simulation Initiative (PSI) Ontology Suite	engineering design and performance	2008	https://link.springer.com/chapter/10.1007/978-3-540-87877-3_9	Yes
Networked Ontologies from the Fisheries Domain	fisheries	2009	https://link.springer.com/chapter/10.1007/978-3-642-04590-5_29	No
Marine Metadata Interoperability Project	oceanography	2009	http://ieeexplore.ieee.org/document/5422206/	No
Infectious Disease Ontology (IDO) suite	infectious diseases	2010	https://link.springer.com/chapter/10.1007/978-1-4419-1327-2_19	Yes
Semantic Publishing and Referencing Ontologies (SPAR)	document description	2014	https://link.springer.com/chapter/10.1007/978-3-319-04777-5_5	No

Annex B
(informative)

The definition of 'ontology'

B.1 Use of 'ontology' in philosophy and computer science

The term '*ontology*' was first used by philosophers as a Latin counterpart of 'metaphysics'. The term was adopted by computer scientists to signify 'a specification of a representational vocabulary for a shared domain of discourse — definitions of classes, relations, functions, and other objects'[8].

'Ontology' is defined within the OWL community as 'a set of precise descriptive statements about some part of the world (usually referred to as the *domain of interest* or the *subject matter* of the ontology)'[4].

B.2 Legacy definitions of 'ontology' in ISO standards

Existing ISO definitions of 'ontology' are:

a) formal representation of phenomena of a universe of discourse with an underlying vocabulary including definitions and axioms that make the intended meaning explicit and describe phenomena and their interrelationships (from ISO 19101-1[9]; reused in ISO 19150-2:2015, 4.1.29[10] and in ISO 19154:2014, 4.16[11])

b) specification of concrete or abstract things, and the relationships among them, in a prescribed domain of knowledge (from ISO/IEC 19763-3:2010, 3.1.1.1[5])

c) a logical structure of the terms used to describe a domain of knowledge, including both the definitions of the applicable terms and their relationships. ISO/IEC/IEEE 24765:2010, 3.1968[12] (from IEEE Std 1175.1-2002 (R2007), 3.9[13])

d) organization of concepts for which a rational argument can be made (from ISO/TR 13054:2012, 2.6[14])

e) explicit and consensual specification of concepts of an application domain independent of any use of these concepts (from ISO 18435-3:2015, 3.1[15])

f) rigorous conceptual schema representing the subject domain (from ISO/TR 25100:2012, 2.1.5[16])

g) a lexicon of specialized terminology along with some specification of the meaning of terms in the lexicon (from ISO 18629-11:2005, 3.18[17])

h) model that represents a domain and is used to reason about the objects in that domain and the relations between them (from ISO/IEC 18384-3:2016, 3.3[18])

i) conceptualisation of a domain (ISO/TS 21526:2019, 3.36[19])

None of these definitions explicitly foresees the possibility of a top-level (in the sense of 'domain neutral') ontology in the sense defined in this document. When they are interpreted in a way that allows for this possibility, however, then definition 3.14 is consistent with all of them. Definition a), which derives from a standard influenced by members of the OWL community, is closest to the definition in this document.

B.3 Definition of ontology-related terms in this document

B.3.1 Scope of application

Definition 3.14 is formulated in such a way as to apply equally to ontologies created under the OWL paradigm and to legacy ontologies, some of which were created under different paradigms and which, even where they exist in OWL versions, retain features not explicitly allowed for in the OWL framework. Note that in the OWL 2 and CL formalizations of an ontology the content of a definition is expressed using one or more axioms.

B.3.2 Collection

The term 'ontology' is sometimes used in a narrow sense to refer to specific sets of axioms. In this document, however, an ontology is conceived in a wider sense as an artefact created by human beings in time, comparable in this respect to a scientific theory or to a lexicon (or to a collection of fossils). An ontology in this wider sense may exist in different languages, and it may exist in different versions at different times, for example as a result of the fact that errors are corrected or new terms added. In the OWL 1 literature an ontology is defined as: a collection of information, generally including information about classes and properties [2].

B.3.3 Entities

The term 'entity' is employed in many ontology communities as an all-inclusive term including everything whatsoever, whether or not it is perceivable or measurable, thus including physical things, attributes, qualities, powers, institutions, languages, theories, types, classes, events, information systems, and so forth. Various alternative terms have played the role of all-inclusive term in contemporary ontology, including 'class', 'concept', 'notion', 'individual', 'term', 'type' and 'item'. In OWL 'Thing' represents the set of all individuals [2]; in the OWL documentation 'Entity' is sometimes used to refer to the union of: Classes, Datatypes, Object Properties, Data Properties, Annotation Properties, and Named Individuals[2]. An influential definition of 'entity' as 'anything perceivable or conceivable' (in ISO 1087-1:2000 (3.1.1)[20]) allows the term 'entity' to be used also to represent for example what is planned or postulated. This definition is modified in this document (3.1) to satisfy the rule that a definition is substitutable in a sentence for the term defined.

B.3.4 Terms

Ontologies are often represented in visualization tools as graph-theoretical artefacts involving nodes and edges. The nodes and edges of such graphs are associated with what are here referred to as 'terms' and 'relational expressions', respectively.

Examples of general terms in natural language are common nouns and noun phrases such as: 'electron', 'explosion', 'hydraulic system', 'phosphorylation', 'nuclear reactor', and 'spatial region'. Examples of such expressions in technical languages include: model numbers, disease codes, and aircraft type designators.

Examples of terms referring to particulars in natural language are proper names such as 'Donald J. Trump'. Examples of such expressions in technical languages include serial numbers, social security numbers, dates, and latitude and longitude coordinates.

In many ontology communities, the terms in an ontology consist of common nouns and noun phrases drawn either from a natural language or from a natural language extended by technical terms or by alphanumeric codes employed in the corresponding domain. When an ontology is structured as a collection of terms representing what is general in this way, then the entities represented are referred to as classes or types. For example, they represent the class whose members are all human beings, or the type whose instances are all glucose molecules.

In some ontology communities, terms such as 'type', 'kind', 'universal', or 'concept' are used as synonyms of 'class'. In other ontology communities, the term 'class' is used to refer not to the type but to the corresponding extension understood set-theoretically. In either case, classes or types are referred to by general terms. In *W3C Recommendation — OWL 2 Web Ontology Language Document Overview*, the term 'Class' is defined informally as: a group of Individuals that belong together because they share certain properties. In Reference [3] it is stated that:

> every OWL Class is associated with a set of Individuals, called the Class Extension. The Individuals in this set are called the Instances of the Class. A class has an intensional meaning (the underlying concept) which is related but not equal to its class extension. Thus, two classes may have the same class extension, but still be different classes.

In *W3C Recommendation — OWL 2 Web Ontology Language Document Overview*, 'Class Description' is used to refer to what in other W3C recommendations is informally called a Class Definition.

Some ontologies also allow terms representing certain privileged particulars (referred to as 'distinguished individuals'), such as 'the actual world', 'spacetime', or (in an ontology of US law) 'the US Supreme Court'.

General terms in a natural language (or in a natural language extended by technical terms or domain-specific codes) correspond in OWL to Classes and Class Expressions and in FOL to unary predicates. Terms in a natural language denoting distinguished individuals correspond in OWL to Named Individuals and in FOL to individual constants.

B.3.5 Relational expressions

To formulate definitions and axioms, terms in an ontology are combined with relational expressions such as 'is_a', 'subclass', 'part_of', 'has_part', and so forth. Verbs and prepositions are in some ontologies used as relational expressions, as for example when 'gives' is used to express the ternary relation between giver, receiver, and gift, or 'in' is used to express the binary relation of spatial containment.

In some ontology communities, relational expressions are syncategorematic; that is to say, they have no meaning in their own right (and thus *a fortiori* they do not refer to any entity in their own right) but only in conjunction with other expressions. In other ontology communities, relational expressions are treated as terms designating relational entities, for example sets of ordered tuples. The use of 'relational expression' in this standard is intended to be neutral as between these two usages.

Relational expressions in a natural language (or in a natural language extended by technical terms or domain-specific codes) correspond in OWL to Properties and in FOL to n-ary predicates for $n \geq 2$.

The role of terms, relational expressions and definitions in ontologies formulated using OWL is summarized as follows:

> In order to precisely describe a domain of interest, it is helpful to come up with a set of central terms – often called a vocabulary – and fix their meaning. Besides a concise natural language definition, the meaning of a term can be characterized by stating how this term is interrelated to the other terms. A terminology, providing a vocabulary together with such interrelation information constitutes an essential part of a typical OWL 2 document. Besides this terminological knowledge, an ontology might also contain so-called assertional knowledge that deals with concrete objects of the considered domain rather than general notions[4].

Annex C
(informative)

Examples of documentation demonstrating breadth of coverage

Table C.1 lists selected abbreviated examples of possible responses to questions raised in subclause 4.4.6. These are based on more detailed specifications provided in ISO/IEC 21838-2 and ISO 15926-2[6], respectively.

Table C.1 — Sample documentation of breadth of coverage in two top-level ontologies

	ISO/IEC 21838-2	ISO 15926-2
Space and time	Basic Format Ontology (BFO) divides all entities into continuants and occurrents; recognizes classes of spatial, temporal and spatiotemporal regions.	The TLO of ISO 15926 is a fourdimensionalist ontology; particulars are in every case spatiotemporal extents that are part of some possible world.
Actuality and possibility	Recognizes only actually existing entities; employs actual entities called 'dispositions' to deal with data about what is merely possible; dispositions may or may not be realized.	One possible world is the actual world which we inhabit; comparisons can be made between, for example, planned possible worlds and the actual world.
Classes and types	Accepts both universals and instances as first-class entities; instances are in every case particulars; higher-level universals (universals instantiated by universals) are not recognized.	Views classes as sets, and thus as defined by their membership; members of a class may be possible individuals from one or more possible worlds, classes, or relationships.
Time and change	Views occurrents as having all their parts and attributes as a matter of necessity; continuants, in contrast, may gain and lose parts or change their attributes while preserving their identity over time.	One possible individual may be a temporal part of another possible individual; a whole life individual of a given type is a possible individual with maximal temporal extent for that type; change is viewed as different possible individuals that are temporal parts of a whole life individual having different attributes or relations.
Parts, wholes, unity and boundaries	Views objects (for example, organisms or lumps of solid matter) as material entities marked by causal unity and separation from their surroundings); includes a distinction between objects, fiat object parts, and object aggregates	Uses a classical mereology extended to four dimensions; a possible individual is any piece of spacetime in some possible world demarcated by any combination of natural or fiat boundaries; recognizes mereological sums and arranged individuals whose parts are arranged in such a way that the whole has emergent properties.
Space and place	Distinguishes spatial regions, represented in coordinate systems, and sites, including places, cavities, conduits; sites are not identical to spatial regions, since a site, for example Paris, can change in size and shape.	All particulars are spatiotemporal extents, including places, locations, and holes; these can have geometric representations in co-ordinate systems; a city is a spatiotemporal extent with temporal parts (states) that have different sizes and shapes.
Scale and granularity	Supports perspectives associated with different granularities (for example, of cells, organs, organisms and populations); entities on a given level of granularity are parts of entities on higher levels of granularity.	Supports different levels of granularity, from the sub-atomic through to an entire possible world (a whole universe extended over all time); views possible individuals at higher levels of granularity as consisting of parts that exist at lower levels.

Table C.1 *(continued)*

	ISO/IEC 21838-2	ISO 15926-2
Qualities and other attributes	Views attributes as standing to their bearers in the relation of specific dependence; the redness of this rose is an instance of the quality red which is a subtype of the quality colour.	Views attributes as classes that have a classification relationship to the possible individuals that have the corresponding attribute; thus, red is a class that classifies those possible individuals that have that colour.
Quantities and mathematical entities	A quantitative attribute such as 63 °C temperature is a subclass of the quality *temperature*; views mathematical theories as resources external to ontology; treats mathematical formulae as information artefacts.	A temperature is a particular degree of hotness that classifies those possible individuals that have that degree of hotness; there is an isomorphic mapping from the set of such temperatures to a number space on some scale, such as the Celsius scale.
Processes and events	Recognizes processes (for instance of location change, quality change, and gain and loss of parts); does not recognize a separate category of attributes of processes, treats process attributions using the machinery of defined classes.	Recognizes events as spatiotemporal planes that mark the beginnings or endings of possible individuals; recognizes activities which cause events; an activity is composed of its participants which are the temporal parts of those whole life individuals that participate in the activity during the times when they participate.
Constitution	Identifies each material entity with the material of which it is made at any given time; for example, a person is identical with an organism which is in turn identical with a certain material entity; an organization is identical with the totality of its members at any given time, whereby these members will at relevant times have organizational roles (duties and responsibilities) specific to this organization.	A physical object consists of the mereological sum of those physical objects at a lower level of granularity that are its parts; a whole life physical object is not necessarily identical to the whole life physical object that constitutes it: a plastic cup made from a piece of plastic is identical to the piece of plastic while it is cup shaped; but the piece of plastic exists before and after it has this shape, and thus is a different whole life possible individual.
Causality	Treats causality under two headings: causal unity of objects; and triggering of dispositions.	An activity causes an event which is a spatiotemporal plane that marks the beginning or ending of a possible individual.
Information and reference	Recognizes the category of generically dependent continuants, which serves as starting point for the population of the Information Artefact Ontology (IAO), an ontology external to BFO, which recognizes a relation of aboutness between information entities and their referents.	A sign is a possible individual that represents something (for example this sign “P101” represents a particular pump); each sign is an instance of a pattern, and each pattern is a class of information representations; different representations of a thing by a pattern may have different user groups (such as English speakers).
Artefacts and socially constructed entities	Uses categories of material entity and function to define classes of material artefacts; treats socially constructed entities in terms of corresponding information entities; thus, an employment contract is a directive information entity describing certain roles.	Treats artefacts as classes of objects created to perform a particular function; recognizes a class of functional physical object for components of systems that retain identity even when replacement occurs, as when heat exchangers in process plants are replaced from time to time; treats organizations as consisting of the temporal parts of the persons who are members of the organization.
Mental entities; imagined entities; fiction; mythology; religion	Mental entities are dealt with through BFO extension ontologies such as the Mental Functioning Ontology; the latter deals also with acts of imagination; data pertaining to fiction, mythology and religion are dealt with through the Information Artifact Ontology; religious beliefs and practices are dealt with in terms of dispositions of individuals and groups	Imagined entities, such as plans, mythology and fiction, are dealt with through possible worlds; see also, actuality and possibility.

Annex D
(informative)

Conformance of a domain ontology to a TLO

D.1 Overview

Where a TLO serves as starting point for the development, or for the re-engineering, of a domain ontology, the conformance of the latter to the TLO in the sense of definition 3.23 should be established in one or more of the following ways.

D.2 Conformance through direct extension

The TLO is loaded into an ontology editor and the domain ontology is constructed *ab initio* on this basis. Terms in the TLO are then used as starting point for defining the topmost set of domain ontology terms as specializations of the relevant TLO categories. Categories shall be used for this purpose that are at the lowest level in the TLO hierarchy suitable for definition purposes in each case, and in any case at a level below ‘entity’. Conformance for a domain ontology constructed in this way requires:

(1) that the result of adding the domain ontology terms and relational expressions to the TLO is a consistent ontology.

In addition, it requires that each term in the domain ontology is either

(2a) connected to the TLO via some unique chain of is-a relations,

or

(2b) able to be defined through some logical combination of terms satisfying (2a) but not itself such as to satisfy (2a).

Adding a domain ontology to a TLO in this way will in some cases result in a conservative extension of the TLO (thus no more theorems using only terms and relational expressions in the signature of TLO will be provable using the TLO extended by the domain ontology than are provable using the TLO alone). In some cases, however, because the domain ontology incorporates a more detailed treatment of terms used in the TLO, the result will not be a conservative extension.

EXAMPLE Where a physics ontology incorporates a more granular axiomatic treatment of the time and space categories defined in a TLO, the result will not be a conservative extension of the TLO.

D.3 Conformance through indirect extension

A domain ontology that is itself a specialization of a second domain ontology can inherit conformance to a TLO by application of the principles specified above not to the TLO but to its domain ontology parent or parents, providing that the latter are themselves conformant to the TLO.

D.4 Conformance through re-engineering

A domain ontology not initially conformant to a TLO may be transformed into an ontology that is conformant. This is achieved, first, by adjustment of its treatment of its upper level terms and of relational expressions in such a way that they satisfy (1) and (2a) or (2b) above, and second by adjustment of successive layers of child terms to ensure that there are chains of is-a relations connecting the lower level terms in the domain ontology to terms in the TLO.

D.5 Validating conformance to a TLO

D.5.1 Validating conformance to a TLO of ontologies axiomatized using OWL or CL

To validate that the ontology that results from applying the above mechanisms conforms to a TLO it shall be shown (i) that the result of combining this ontology with the TLO is itself a consistent ontology, and (ii) that the TLO is logically interpretable within it. For OWL ontologies (i) and (ii) are demonstrated through use of standard reasoners. For CL ontologies (i) and (ii) are addressed through the methods outlined in 4.4.4 and 4.4.5.

D.5.2 Validating conformance for ontologies axiomatized in a syntax other than OWL 2 or CL

To determine that an ontology formulated in a language or syntax other than OWL 2 or CL is conformant to a TLO as defined in this document it shall be shown:

1. that there exists a mapping of the terms and relational expressions in the ontology as expressed in this language to terms and relational expressions in OWL 2 or CL;

2. that the range of this mapping includes terms and relational expressions in the corresponding (OWL 2 or CL) axiomatization of the TLO. The set of terms so mapped is the TLO sub-signature of the ontology;

3. that the entailments of axioms of this ontology that use only terms and relational expressions from this sub-signature map to a subset of the entailments of the TLO.

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