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Information technology — Top-level ontologies (TLO) —

Part 4:
TUpper

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 32, *Data management and interchange*.

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Introduction

TUpper is a top-level ontology (TLO) conforming to ISO/IEC 21838-1. It contains definitions of its terms and relational expressions and formal representations in OWL 2 and in Common Logic (CL).

Top-level ontologies have traditionally arisen from the approach in which concepts that are common across a set of domains can be axiomatized at a general level. The rationale is that reuse across domains is to be supported through specialization of the general concepts from a top-level ontology. Similarly, semantic integration between ontologies is to be achieved through the general concepts they specialize. The TUpper ontology follows an alternative approach (referred to as the sideways approach) to the conventional top-level ontology paradigm. Rather than think of a top-level ontology as a monolithic axiomatization centred on a taxonomy, the sideways approach considers a top-level ontology to be a modular ontology composed of ontologies that cover concepts including those related to time, process, and space, from which any underlying taxonomy can be inferred. Each module within TUpper is a set of axioms from an existing ISO standard. The central claim is that a top-level ontology is an ontology that has a reduction whose modules are all ontologies that satisfy a subset of the requirements for a top-level ontology in ISO/IEC 21838-1:2021. New top-level ontologies can be designed by the union of different ontologies that already exist rather than harmonizing different ontologies.

The TUpper ontology is designed as a top-level ontology that contains modules from the ontologies within existing international standards, and that extends these modules so as to satisfy the criteria for top level ontologies in ISO/IEC 21838-1. The modules of PSL appear in ISO 18629. The modules for mereotopology and location arise from ISO 19107 and ISO 19150-1. Modules related to units of measure arise from ISO 80000.

TUpper-terms, the natural language specification of TUpper, supports human maintenance and use of the ontology, including use in development of conformant domain ontologies.

Tupper-OWL, the OWL 2 formalization of TUpper, enables TUpper to be integrated with other ontologies expressed in OWL and in related languages, and supports the use of OWL automated reasoners.

TUpper-CL, the CL formalization of TUpper, provides the axiomatization of the intended semantics of TUpper.

This document conforms to ISO/IEC 21838-1.

Information technology — Top-level ontologies (TLO) —

Part 4:
TUpper

1 Scope

This document describes TUpper as an ontology that is conformant to the requirements specified for top-level ontologies in ISO/IEC 21838-1.

This document describes TUpper as a resource designed to support ontology design, ontology integration, automated reasoning, and semantic integration of heterogeneous information systems.

The following are within the scope of this document:

— definitions of classes and relations in the signature of TUpper;

— axiomatizations of TUpper in OWL 2 and CL;

— documentation of the conformity of TUpper to the requirements specified for top-level ontologies in ISO/IEC 21838-1;

— documentation of the methodology for specifying domain ontologies that conform to TUpper.

The following are outside the scope of this document:

— specification of ontology languages, including the languages RDF, OWL and CL standardly used in ontology development;

— specification of methods for reasoning with ontologies;

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

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 21838-1:2021, *Information technology — Top-level ontologies (TLO) — Part 1: Requirements*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO/IEC 21838-1 and the following 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 https://www.electropedia.org/

3.1
conservative extension
superset of axioms from which no new theorems in the signature of the original logical theory are provable

3.2
consistent extension
supserset of axioms which is a consistent logical theory

3.3
logically synonymous, adj
theories whose sets of models are in a one-to-one correspondence

3.4
module
subset of the axioms in a formal theory that is a *conservative extension* (3.1) of the subset

3.5
reduction
set of logical theories whose union is *logically synonymous* (3.3) to the ontology

4 Conformance of TUpper to ISO 21838-1

4.1 Overview

TUpper has three elements the documentation of which is provided in the file Tupper-Terms at https://standards.iso.org/iso-iec/21838/-4/ed-1/en/:

— natural language representation of its terms, relational expressions and definitions;

— formalization in OWL 2 (Web Ontology Language);

— formalization in CL (Common Logic).

4.2 Natural language representation of TUpper

The natural language representation of TUpper, provided in the file TUpper-Terms at https://standards.iso.org/iso-iec/21838/-4/ed-1/en/, establishes conformance of TUpper to ISO/IEC 21838-1:2021, 4.1.

4.3 OWL 2 formalization of TUpper

The OWL 2[15],[16],[17] formalization of TUpper, provided in the file TUpper-OWL at https://standards.iso.org/iso-iec/21838/-4/ed-1/en/, establishes conformance of ISO/IEC 21838-1:2021, 4.2.

4.4 Common Logic axiomatization of TUpper

4.4.1 General

The CL formalization of TUpper (provided at https://standards.iso.org/iso-iec/21838/-4/ed-1/en) to ISO/IEC 21838-1:2021.

TUpper is available in the following formats:

— axiomatization in Common Logic Interchange Format (CLIF) as specified in ISO/IEC 24707 provided in the **common-logic** directory;

— axiomatization in standard first-order predicate logic notation is provided in the **pdf** directory.

4.4.2 Modularity

The axioms in TUpper-CL are divided into the following modules in accordance with the requirement of explicit modularization in ISO/IEC 21838-1:2021, 4.1.

PSL-Core	Duration of Objects and Activity Occurrences	Length
PSL Subactivity	Duration Ontology	Area
PSL Occurrence Trees	Timedurations	Volume
PSL Discrete States	Physical Mass	Density
PSL Atomic Activities	Constitution	Velocity
PSL Complex Activities	Mass	
PSL Activity Occurrences	Chunks of Matter	
PSL Interval Time	Amounts of Matter	
PSL Actors	Multidimensional Mereotopology	
Location Ontology	Shape	
Mereology for Location	Multidimensional Location Ontology	
Topology for Location	Length of Physical Objects	
Physical Mereology	Area of Physical Objects	
Physical Topology	Volume of Physical Objects	
Spatial Topology		

4.5 Specification of the purpose of TUpper (in conformance to ISO/IEC 21838-1:2021, 4.4.2)

The TUpper ontology is designed as a top-level ontology that consistently combines the ontologies within existing international standards[1],[2],[3],[4],[5],[6],[7],[8],[9],[10],[11],[12],[13],[14]. Such an ontology enables applications that require the use of the multiple standards that are conformant with TUpper.

— ISO 18629-11: PSL-Core

— ISO 18629-12: PSL-Subactivity, PSL Occurrence Trees, PSL Discrete States, PSL Atomic, PSL Complex Activities, PSL Activity Occurrences, PSL Interval Time

— ISO 18629-13: PSL Duration

— ISO 19107: Multidimensional Mereotopology

— ISO/TS 19150-1: Occupy Root, Physical Mereotopology, Spatial Mereotopology

— ISO/IEC 80000: PSL Duration, Physical Mass, Spatial Units of Measure

4.6 Conformance of a domain ontology to TUpper (in conformance to ISO/IEC 21838-1:2021, 4.4.3)

A domain ontology conforms to TUpper if and only if the axioms are specified in a CL dialect and the set of axioms is a consistent extension of the axiomatization of TUpper as specified in the same CL dialect.

4.7 Consistency of the CL axiomatization of TUpper (in conformity to ISO/IEC 21838-1:2021, 4.4.4)

The logical consistency of TUpper follows from the verification of the ontology, in which TUpper is shown to be logically synonymous with the union of a set of mathematical theories. The verification is done on the set of modules in TUpper and is provided at https://standards.iso.org/iso-iec/21838/-4/ed-1/en/verification/.

4.8 Interpretability of the OWL 2 axiomatization of TUpper in the CL axiomatization (in conformity to ISO/IEC 21838-1:2021, 4.4.5)

Interpretability of the OWL 2 axiomatization described in TUpper-OWL in the CL axiomatization (provided at https://standards.iso.org/iso-iec/21838/-4/ed-1/en/owl-interpret/) was established by incorporating a CL counterpart of the OWL axiomatization into the CL axiomatization

4.9 Demonstration of breadth of coverage of TUpper (in conformance to ISO/IEC 21838-1:2021, 4.4.6)

4.9.1 General

This subclause provides a set of answers to the questions listed in ISO/IEC 21838-1:2021, 4.4.6 demonstrating the breadth of coverage of TUpper.

4.9.2 Space and time

TUpper posits two classes of temporal entities – timepoints (over which an ordering relation is axiomatized) and time intervals (which extend in time and over which an ordering and a mereology are defined).

TUpper recognizes entities that persist in time – an object exists at timepoints between the timepoint at which it starts to exist and the timepoint at which it ceases to exist.

TUpper recognizes entities that occur in time – each activity occurrence occurs at timepoints between the timepoint at which it starts to occur and the timepoint at which it ceases to occur.

TUpper axiomatizes a mereotopology over the set of spatial regions.

4.9.3 Actuality and possibility

Models of psl_occtree.clif are occurrence trees, which consist of all possible sequences of atomic activity occurrences. The set of activities that actually occur in a model are elements of one branch of the occurrence tree. Models consist of subtrees of the occurrence tree that correspond to possible occurrences of complex activities. A legal occurrence tree is the subtree of an occurrence tree in which all activity occurrences satisfy precondition axioms that specify the conditions under which an activity can possibly occur. Dispositions are treated via such precondition axioms.

4.9.4 Classes and types

Classes of activities are definable within TUpper. Classes of classes do not appear within the ontology, although they are allowed within the language of Common Logic.

4.9.5 Change over time

Within TUpper, changeable properties are represented by states. States are achieved and falsified by activity occurrences.

Modules of TUpper that axiomatize domain process ontologies classify the activities that change states that are associated with different domains. The module motion.clif within TUpper classifies all activities that can possibly change the location of an object. It is consistent with TUpper for more than one material object to occupy exactly the same spatial region at the same time. The module matter.clif within TUpper all activities that can change the mereology of matter and that can change a material object by changing the matter that constitutes the object.

4.9.6 Parts, wholes, unity and boundaries

TUpper adopts multiple distinct parthood and connection relations for different classes of entities. The mereologies on matter and spatial regions are complete extensional mereologies with complementation, as is the mereology of atomic (concurrent) activities. On the other hand, the mereology of complex activities is logically synonymous with the weakest mereology, and does not require the existence of sums or complements. The mereology on components and time intervals entails Strong Supplementation, but does not require the existence of sums for all elements.

4.9.7 Space and place

TUpper axiomatizes distinct mereotopologies for material objects and spatial regions, with the occupy relation specifying the relationship between the object and the region that it occupies. The module occupy_root.clif contains the axiomatization of the location ontology within TUpper.

Shape is represented topologically in the boxworld.clif module of TUpper. Holes are specified as physical objects which have shape but which are not constituted by matter.

4.9.8 Scale and granularity

TUpper does not explicitly represent scale and granularity, although granularity can be specified for entities which have a parthood relation (e.g. material objects, activities, activity occurrences, and spatial regions).

4.9.9 Qualities and other attributes

TUpper does not reify qualities, that is, there is no class of qualities within the ontology. Instead, the intended semantics of attributes and properties appear as relations in the signatures of the modules of TUpper. For example, attributes and properties for shape are represented by classes and relations within the signature of the Shape module, and duration is represented by classes and relations in the signature of the modules for the Duration of Objects and Activity Occurrences.

4.9.10 Quantities and mathematical entities

TUpper axiomatizes the units of measure, constraints on how units can be algebraically manipulated, and the relationship between physical objects and processes and the units of measure.

4.9.11 Processes and events

Processes appear as the class of complex activities which have nontrivial subactivities. Fluents (states) are achieved or falsified by activity occurrences, and only activity occurrences can change fluents. Processes are therefore distinct from change, but are associated with the ways in a fluent can change.

There are no constraints on the kinds of processes that exist. Classes of processes are defined in extensions of the ontology.

Each activity occurrence has a duration, which can be zero in the case of an instantaneous activity occurrence (i.e. one in which the beginof timepoint is equal to the endof timepoint).

4.9.12 Constitution

The module constitution.clif axiomatizes the constitutes relation between an object and its matter. Constitution only holds between objects and matter, and there is no analogue of constitution that holds between processes or nonmaterial entities.

4.9.13 Causality

Causal constraints are definable between activities, as well as between activities and fluents (states). In particular, one activity can achieve the preconditions of another activity, or a fluent may trigger the occurrence of an activity.

4.9.14 Information and reference

Information entities per se are not elements of the TUpper ontology. The contents of an information entity such as a database are represented by logical theories that use the ontology.

4.9.15 Artefacts and socially constructed entities

As socially constructed entities, actors are entities that make decisions, and agents are entities that have goals and commitments.

4.9.16 Mental entities, imagined entities, fiction, mythology, religion

TUpper does not deal with mental or imagined entities.

4.10 Documentation of ontology management principles (in conformance to ISO/IEC 21838-1:2021, 4.4.8)

The name and contact information of the maintenance agency for this document can be found at https://www.iso.org/maintenance_agencies.html.

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