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Information technology — Top-level ontologies (TLO) —

Part 2: Basic Formal Ontology (BFO)

Technologies de l'information — Ontologies de haut-niveau (TLO) —

Partie 2: Ontologie formelle de base (BFO)

Reference number
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

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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*.

A list of all parts in the ISO/IEC 21838 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

Basic Formal Ontology (BFO) is a top-level ontology (TLO) conforming to ISO/IEC 21838-1. It contains (i) definitions of its terms and relational expressions and (ii) formalizations in OWL 2 and in Common Logic (CL). BFO is a public-domain resource introduced in 2002. It is an ontology of highly general terms designed to support the interoperability of data and information systems associated with ontologies containing more specific terms relating to specific domains. The primary goal of BFO is to support the development of such domain ontologies in a way that promotes the coordination of ontology development by different groups in a way that promotes consistency and non-redundancy. BFO was initially conceived as part of a strategy to advance coordinated domain ontology development across the life sciences. BFO has since been used for similar purposes in other areas, including data and information science, sustainable development, and in the engineering, military and intelligence fields. This document was developed as a response to the need for a TLO designed to support information system interoperability expressed by ontology users in these and other areas.

BFO is a domain-neutral ontology. This means that it provides terms representing only highly general categories – such as object, quality, process, spatial and temporal region – which pertain to all domains of reality.

BFO has existed thus far in four major release versions.

Version 1.0 (released in 2002)

Version 1.1 (released in 2007)

Version 2.0 (released in 2015)[7]

Version 2020 (released in 2020)[10], [11]

Through these successive versions the categorial core of BFO, resting on a distinction between continuants and occurrents, and between dependent and independent entities, has remained constant. Version 1.1 added the new category of generically dependent continuant, which was introduced to provide a starting point for definitions of terms representing information artefacts and other dependent entities (such as nucleic acid sequences) which can exist in multiple copies. Version 2.0 differs from its predecessors in a series of minor changes which flowed from a major re-formalization using the OWL 2 language[3].

The BFO-2020 category hierarchy is illustrated in Figure 1. This extends the category hierarchy of BFO 2.0 through the inclusion of two terms ("temporal instant" and "temporal interval") and through the renaming of terms relating to fiat boundaries. BFO-2020 also adds a systematic repertoire of inverse relations to the relations in BFO 2.0 and an enriched treatment of relations involving time.

BFO-2020-Terms, the natural language specification of BFO-2020, supports human maintenance and use of the ontology, including use in development of BFO-conformant domain ontologies.

BFO-2020-OWL, the OWL 2 formalization of BFO-2020, supports use of the ontology in computing, including enabling BFO-2020 to be used in tandem with other ontologies expressed in OWL and in related languages, and in allowing ontology quality control through use of OWL reasoners.

BFO-2020-CL, the CL formalization of BFO-2020, provides the expressivity needed to capture the formal structures used by BFO-2020, for example in its treatment of time, space and parthood.

This document conforms to ISO/IEC 21838-1.

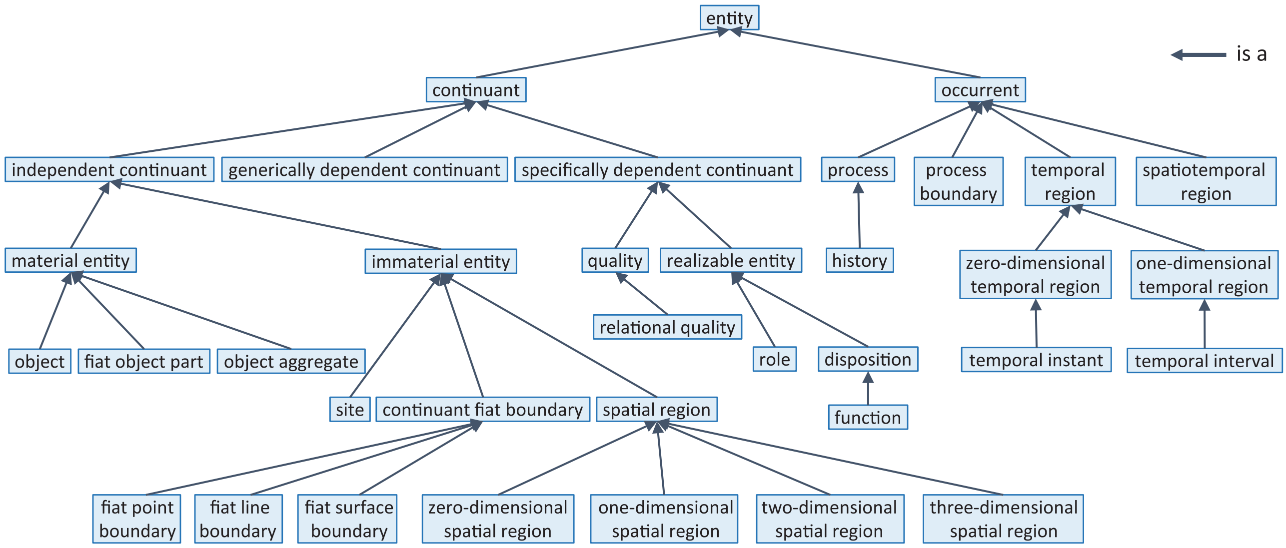

Figure 1 — BFO-2020 is_a hierarchy

Information technology — Top-level ontologies (TLO) —

Part 2: Basic Formal Ontology (BFO)

1 Scope

This document describes Basic Formal Ontology (BFO), which is an ontology that is conformant to the requirements specified for top-level ontologies in ISO/IEC 21838-1.

It describes BFO as a resource designed to support the interchange of information among heterogeneous information systems. The following are within the scope of this document:

— definitions of BFO-2020 terms and relations;

— axiomatizations of BFO-2020 in OWL 2 and CL;

— documentation of the conformity of BFO-2020 to the requirements specified for top-level ontologies in ISO/IEC 21838-1;

— specification of the requirements for a domain ontology if it is to serve as a module in a suite of ontologies in which BFO serves as top-level ontology hub by providing a starting point for the introduction of the most general terms in those domain ontologies which are its nearest neighbours within the suite;

— specification of the role played by the terms in BFO in the formulation of definitions and axioms in ontologies at lower levels that conform to BFO.

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given 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 http://www.electropedia.org/

NOTE The following terms and definitions, along with the definitions in ISO/IEC 21838-1, form part of the meta-vocabulary used for describing BFO-2020 in this document, except that in BFO the terms "entity" and "object" are not synonyms. The vocabulary of BFO-2020 itself is documented in https://standards.iso.org/iso-iec/21838/-2/ed-1/en.

3.1
primitive
expression for which no non-circular definition can be provided

3.2
universal
type
entity (3.1) that has indefinitely many *instances* (3.6)

EXAMPLE Electron, molecule, cell, planet, explosion, vehicle, hour, traffic law, organization, mortgage contract, email message.

Note 1 to entry: References to universals are employed in the formulation of the assertions of natural science and of analogous general assertions in technical manuals, experimental protocols or legal or administrative documents.

3.3
extension
collection (3.4) of instances of a *universal* (3.2)

Note 1 to entry: In OWL, every Class is associated with a Class Extension, which is the set of Instances of the Class. In Reference [4] (from 2004), it is asserted that: "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."

3.4
collection
group of particulars

Note 1 to entry: The particulars in a collection are called its members.

Note 2 to entry: The term "collection" is to be understood as allowing change of members over time (see ISO/IEC 21838-1:2021, B.3.2).

3.5
defined class
collection (3.4), whose members are defined by specifying a restriction on one or more *universals* (3.2), that is not the *extension* (3.3) of any *universal* (3.2)

EXAMPLE Non-smoker (meaning: person who does not smoke); pet (meaning: animal that is kept for companionship or pleasure); mortgagee (meaning: person with a mortgage); lathe operator (meaning: person with an employment role realized through operating a lathe); target (meaning: thing or process that is targeted).

Note 1 to entry: In the OWL 2 community the expression "Defined Class" is sometimes used informally to refer to those Classes in an ontology in which both necessary and sufficient conditions are provided, as contrasted with what are called "Primitive Classes" for which only necessary conditions are provided.

3.6
instance
particular that instantiates some *universal* (3.2)

EXAMPLE John, John’s laptop, the year 2012.

4 Conformity of BFO-2020 to ISO/IEC 21838-1

4.1 Overview

BFO-2020 has three elements, the documentation of which is provided at https://standards.iso.org/iso-iec/21838/-2/ed-1/en:

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

b) formalization in OWL 2 (Web Ontology Language);

c) formalization in CL (Common Logic).

NOTE As pointed out in ISO/IEC 21838-1:2021, 4.2.2, alternative OWL axiomatizations of BFO-2020 can be conformant to BFO-2020-CL. On the treatment of such alternative axiomatizations, see 4.8.2.

4.2 Natural language representation of BFO-2020

The natural language representation of BFO-2020, provided in the file BFO-2020-Terms provided at https://standards.iso.org/iso-iec/21838/-2/ed-1/en/ establishes conformity of BFO-2020 to ISO/IEC 21838-1:2021, 4.1.

4.3 OWL 2 formalization of BFO-2020

The OWL 2 formalization of BFO-2020, provided in the file BFO-2020-OWL (https://standards.iso.org/iso-iec/21838/-2/ed-1/en) establishes conformance to ISO/IEC 21838-1:2021, 4.2. BFO-2020-OWL consists of the following parts:

4.3.1 BFO-2020.owl – OWL in rdf format.

4.3.2 BFO-2020.ofn – OWL in functional syntax[8] with URIs.

4.3.3 BFO-2020-labelled.ofn – OWL in functional syntax with labels instead of URIs.

4.3.4 BFO-2020-iris.xlsx – table of IRIs for all classes and relations in BFO-2020-CL, including all classes and relations in BFO-2020-OWL.

4.3.5 bfo-relations-table.xlsx – table showing all relations in BFO-2020 including all inverses and all binary variants used in BFO-2020-OWL.

4.3.6 temporalized-definitions.cl – the set of CL definitions of binary at-all-times/some-time relations used in BFO-2020-OWL.

4.3.7 temporalized-definitions.prover9 – the set of definitions of binary at-all-times/some-time relations used in OWL (as for 4.3.3) but in prover9 format[2].

4.4 Common Logic axiomatization of BFO-2020

4.4.1 General

The CL formalization of BFO-2020 (provided at https://standards.iso.org/iso-iec/21838/-2/ed-1/en) to ISO/IEC 21838-1:2021, 4.3, BFO-2020-CL is provided in the following formats:

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

b) axiomatization using prolog style variables for ingestion in the prover9 automated theorem prover is documented in Reference [2] is provided in the **prover9** directory;

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

4.4.2 Modularity

The axioms in BFO-2020-CL are divided into the following sections in conformance with the requirement of explicit modularization at ISO/IEC 21838-1:2021, 4.1.

Continuant Mereology	Order
Domain and Range	Participation
Existence and Instantiation	Spatial Region
Generic Dependence	Spatiotemporal Region
History	Specific Dependency
Material Entity	Temporal Region
Occurrent Mereology	Universal Declaration

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

4.5.1 General

BFO is designed as a top-level ontology that can serve as a starting point for definitions in suites of domain ontologies in conformance with ISO/IEC 21838-1:2021, 4.4.2. Examples of such suites using BFO in this manner are provided in 4.5.2 and 4.5.3.

4.5.2 Example Open Biomedical Ontologies (OBO)

Bacterial Clinical Infectious Diseases Ontology (BCIDO)	Mental Disease Ontology (MFOMD)
Beta Cell Genomics Application Ontology (BCGO)	Mental Functioning Ontology (MFO)
Biological Collections Ontology (BCO)	Ontology for Adverse Events (OAE)
Cell Ontology (CL)	Ontology for Biobanking (OBIB)
Cell Line Ontology (CLO)	Ontology of Biological and Clinical Statistics (OBCS)
Chemical Entities of Biological Interest (CHEBI)	Ontology for Biomedical Investigations (OBI)
Common Anatomy Reference Ontology (CARO)	Ontology for General Medical Science (OGMS)
Drug Ontology (DRON)	Ontology of Medically Related Social Entities (OMRSE)
Emotion Ontology (MFOEM)	Oral Health and Disease Ontology (OHD)
Environment Ontology (ENVO)	Plant Ontology (PO)
Gene Ontology (GO)	Population and Community Ontology (PCO)
Human Disease Ontology (HDO)	Protein Ontology (PRO)
Infectious Disease Ontology (IDO)	Relations Ontology (RO)
Information Artefact Ontology (IAO)	Vaccine Ontology (VO)

Documentation of these and other OBO Foundry ontologies is provided at http://obofoundry.org.[5]

4.5.3 Example Common Core Ontologies (CCO)

Agent Ontology	Information Entity Ontology

Artefact Ontology
Currency Unit Ontology
Event Ontology
Extended Relation Ontology
Geospatial Ontology
Modal Relation Ontology
Quality Ontology
Time Ontology
Units of Measure Ontology

The CCO suite is extended by a series of application ontologies, including:

Aircraft Ontology
Airforce Aircraft Maintenance Ontology
Army Universal Task List Ontology
Airforce Aircraft Maintenance Ontology
Army Universal Task List Ontology
Emotion Ontology
Hydrographic Feature Ontology
Legal and Criminal Act Ontology
Military Operations Ontology
Mission Planning Ontology
Mission Planning Ontology
Occupation Ontology
Outer Space Ontology
Physiographic Feature Ontology
Sensor Ontology
Skills Ontology
Space Object Ontology
Transportation Infrastructure Ontology
Undersea Warfare Ontology
Watercraft Ontology

Documentation of these and other common core ontologies is provided in Reference [6].

4.6 Description of how conformance of a domain ontology to BFO is established (in conformance with ISO/IEC 21838-1:2021, 4.4.3)

4.6.1 Overview

Where BFO serves as starting point for the development, or for the re-engineering, of domain ontologies or other external ontology resources, the conformance of the latter to BFO in conformance with ISO/IEC 21838-1:2021, 4.4.3 is established in the following ways.

4.6.2 Conformance through direct extension

One common strategy used to ensure conformance of a domain ontology to BFO is to load BFO into an ontology editor and construct the domain ontology ab initio on this basis. Terms in BFO are then used as starting point for defining the topmost set of domain ontology terms as specializations of the relevant BFO categories. Categories shall be used for this purpose that are at the lowest level in the BFO hierarchy suitable for the purposes of the domain ontology, and in any case at a level below "entity". Conformance for a domain ontology constructed in this way requires:

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

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

b1) connected to BFO via some unique chain of is_a relations, or

b2) able to be defined through some logical combinations of terms satisfying b1) but not itself such as to satisfy b1).

In the latter case, the term refers to a defined class (see definition 3.5).

The requirement of uniqueness in b1) implies that all terms in the resulting ontology that refer to universals (in the sense of definition 3.2), rather than to defined classes, form a hierarchy governed by single inheritance (no term in the resulting ontology shall have more than one parent).

Adding a domain ontology to BFO, in some cases, results in a conservative extension of BFO (thus no more theorems using only terms and relational expressions in the signature of BFO will be provable using BFO extended by the domain ontology than are provable using BFO alone). In cases where the domain ontology relates to universals – for example time and space in a physics ontology – which are BFO categories, then the result might not be a conservative extension for example because it contains a more granular treatment of time and space than is provided by BFO.

4.6.3 Conformance through indirect extension

A domain ontology that is itself a specialization of a second domain ontology can inherit conformance to BFO by application of the principles specified above but only to the degree that its parent or parents in the ontology hierarchy themselves conform to BFO.

4.6.4 Conformance through re-engineering

A domain ontology not initially conforming to BFO may be transformed into an ontology that is conforming. 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 4.6.2 a) and b1) or b2), and second by adjustment of successive layers of child terms to ensure that relevant is_a relations obtain.

4.6.5 Validating conformance to BFO

4.6.5.1 Establishing conformance for ontologies formulated in English and using OWL or CL syntax

To validate that the ontology that results from applying the above mechanisms conforms to BFO, it is necessary to demonstrate a) that the ontology is consistent and b) that BFO as specified in this document is logically interpretable within it. For OWL ontologies, a) and b) are addressed through use of standard reasoners. For CL ontologies, a) and b) are addressed through the methods outlined in 4.7 and 4.8, respectively.

4.6.5.2 Establishing conformance for ontologies formulated in a different language or syntax

An ontology may be formulated in a language or syntax different from those used in this document. To determine that such an ontology conforms to BFO it shall be shown:

a) that there exists a mapping of the terms and relational expressions in the ontology as expressed in this language to terms and relational expressed in one of the languages used in this document (OWL 2, CL);

b) that the range of this mapping includes terms and relational expressions in the corresponding representation of BFO; the set of terms so mapped is the BFO sub-signature of the ontology;

c) 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 BFO-2020-CL.

4.7 Specification of how consistency of the CL axiomatization of BFO-2020 is demonstrated (in conformance with ISO/IEC 21838-1:2021, 4.4.4)

4.7.1 Overview

The proof of the consistency of BFO-2020-CL in conformance with ISO/IEC 21838-1:2021, 4.4.4 is provided at https://standards.iso.org/iso-iec/21838/-2/ed-1/en. The first step in the proof is the creation of a reduced CL axiom set formed by removing definitionally equivalent axioms: (i) for relations

R with inverses R', only axioms pertaining to R are retained; (ii) for binary relations BR (provided at https://standards.iso.org/iso-iec/21838/-2/ed-1/en) defined in terms of CL ternary relations TR, only axioms pertaining to TR are retained. Second, standard semantic methods were used to build the model for the reduced theory that is provided at https://standards.iso.org/iso-iec/21838/-2/ed-1/en. An extension of the Clausetester application in the LADR Library for Automated Deduction Research Prover9 suite is used to show that all the axioms of the reduced theory are true in this model, thus proving consistency, since any model in which the reduced theory is true is also true in the expanded theory.

4.7.2 Documentation

BFO-2020 provided at https://standards.iso.org/iso-iec/21838/-2/ed-1/en comprises the model in three different formats, as follows:

— Common logic: model.cl;

— Prover 9 reasoner: model.p9;

— A mace4 format interpretation: mace4-interpretation.txt.

4.7.3 Structure of the model

A model is some domain of individuals together with an interpretation mapping symbols (terms and relational expressions) to individuals and relations over individuals. The theory constituted by the axioms of BFO-2020-CL allows for finite models, and the model used in the proof comprises 2892 relationships in a domain with 98 individuals, as documented in https://standards.iso.org/iso-iec/21838/-2/ed-1/en. The model is given as a structure that consists of a finite set of relationships, each one having a relation symbol from the BFO-2020-CL theory, together with a sequence of individuals.

The individuals in the model are names (arbitrary strings). The model's relations are those that are true when their relation symbol and arguments (names) form one of the relationships in the structure, and false otherwise. Each formula is checked against every possible assignment of quantified variables to the individuals in the domain. Since all formulas are satisfied by this model, the theory is consistent.

4.8 Description of how interpretability of the OWL 2 axiomatization of BFO-2020 in the CL axiomatization is established (in conformance with ISO/IEC 21838-1:2021, 4.4.5)

4.8.1 Interpretability proof strategy for BFO-2020-OWL

Interpretability of the OWL 2 axiomatization described in BFO-2020-OWL in the CL axiomatization described in BFO-2020-CL (provided at https://standards.iso.org/iso-iec/21838/-2/ed-1/en) was established by incorporating a CL counterpart of the OWL axiomatization into the CL axiomatization as follows.

a) OWL 2 axioms were translated into CL syntax.

b) Definitions in CL syntax of the OWL 2 binary relations listed in section 3 of BFO-2020-Terms were created following the pattern:

   b **continuant part of at some time** *c* = Def. for some time *t* (**exists at** *b* and *b* **continuant part of** *c* **at** *t*)

c) The results of 1. and 2., presented in section 3 of BFO-2020-Terms, were incorporated into the CL axiomatization.

d) The CL axiomatization was shown to be consistent. (See 4.7.)

4.8.2 Interpretability for alternative axiomatizations of BFO-2020

4.8.2.1 General requirement on conformant profiles

An ontology may be provided in different versions, sometimes called profiles, subsets, slims, views, or modules, tailored for specific communities or research paradigms. An ontology constructed in this way is a conformant profile of BFO-2020 provided that all assertions derivable from this ontology are provable from the axioms of the CL formalization in BFO-2020-CL.

The following, together with their combinations, are allowable types of conformant profile.

4.8.2.2 Conformant profiles through alternative axiomatization

As described at ISO/IEC 21838-1:2021, 4.2.2, the restrictions on axiom closure in an OWL 2 ontology imply that there may be alternative OWL 2 formalizations of the BFO-2020 signature documented in BFO-2020-Terms that are interpretable in and provable from the CL axiomatization in BFO-2020-CL. Such alternative axiomatizations may incorporate profiles of OWL[3] weaker than OWL 2 with discrete semantics.

Where an ontology satisfies the requirement in 4.8.2.1 but involves an OWL axiomatization that differs from BFO-2020-OWL, this ontology is said to be conformant to BFO-2020 through alternative axiomatization.

EXAMPLE Two axiomatizations employ the BFO-2020 signature but differ in that one uses the EL profile and the other uses the RL profile of OWL 2.

4.8.2.3 Conformant profiles through signature restriction

Where an ontology satisfies the requirement in 4.8.2.1 but differs from BFO-2020 in that its signature is a proper subset of the signature of BFO-2020, this ontology is said to be *conformant to BFO-2020 through signature restriction.*

EXAMPLES (1) A subtheory of BFO-2020-CL designed exclusively for the representation of processes and consisting only of the occurrent terms of BFO-2020 and of the corresponding CL axioms. (2) The 'classes only' OWL profile of BFO 2 at http://purl.obolibrary.org/obo/bfo.owl, which includes only the class hierarchy and subclass and disjointness assertions from the full OWL version of BFO 2, but no Object or Data Properties or logical axioms that use such Properties.

4.8.2.4 Conformant profiles through incorporation of defined classes

Where an ontology satisfies the requirement in 4.8.2.1 but has a signature which includes terms and relational expressions defined logically from the terms and relational expressions in the signature of BFO-2020, this ontology is said to be conformant to BFO-2020 through incorporation of defined classes (see 3.5 and 4.6.2).

EXAMPLE An extension of BFO-2020 created by incorporating into the signature the class "attribute" defined as the disjunction "quality or realizable entity".

4.8.2.5 Conformant profiles through relabelling

Where an ontology satisfies the requirement in 4.8.2.1 but has a signature that involves relabelling of one or more terms or relational expressions while preserving the original IRIs, this ontology is said to be conformant to BFO-2020 through relabelling.

EXAMPLE (1) A replica of BFO-2020, except that the terms and relational expressions are translations of the BFO-2020 signature from English into another language. (2) A subtheory BFO-2020-OWL designed to support the representation of chemical entities (molecules and their parts) and consisting exclusively of continuant terms and associated relational expressions in which BFO-2020-OWL:continuant-part-of-at-all-times is relabelled "continuant-part-of".

4.9 Demonstration of breadth of coverage of BFO (in conformance with with 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 BFO.

4.9.2 Space and time

BFO is divided into a continuant and an occurrent branch; it thus recognizes both entities which persist, for example engineered artefacts and their functions, and entities which occur, for example processes such as occur when engineered artefacts exercise their functions.

BFO incorporates occupies relations between independent continuants and spatial regions of 0, 1, 2 and 3 dimensions, and between processes and both temporal regions of 0- and 1-dimensions and spatiotemporal regions.

4.9.3 Actuality and possibility

BFO is an actualist ontology; this means that it recognizes only actually existing entities (at the level of both instances and universals). Two strategies are available to users of BFO for dealing with data about merely possible entities.

a) By drawing on the category of dispositions, which are actual entities having the feature that they may, but need not, be realized. Functions are one subcategory of disposition in BFO.

b) Engineering designs, chemical diagrams and theoretical speculations in scientific theories are examples of information entities which are conditional, in the sense that they are about something actual only under certain conditions (for example that the relevant design is realized in a corresponding artefact or the relevant chemical is synthesized). BFO users are able to create in such contexts domain ontologies which are conditional in the analogous sense: that is, the content of BFO is used in just the way it would be used if the entities in question were already known to exist in the actual world, but subject to the proviso that the resulting assertions involve no ontological commitment to such entities.

4.9.4 Classes and types

BFO is a realist ontology in the sense that it accepts universals as really existing denizens of reality. This allows BFO users to draw a distinction between reference ontologies and application ontologies. The former, which consist predominantly of terms representing universals, are created for unrestricted reuse in other ontologies. Application ontologies are created for specific application purposes and include terms representing not only universals but also defined classes as described under 4.8.2.4.

BFO is neutral as to whether there may be distinct universals that have identical extensions.

BFO does not recognize higher-level universals (universals instantiated by universals). For example, there is no universal named "universal".

4.9.5 Change over time

BFO takes identity of continuants as something primitive. Objects, for example, may change over time, for example change in qualities or location, while preserving their identity. Occurrents, in contrast, cannot change. Thus, they cannot gain and lose parts.

BFO deals with changes in attributes (such as temperature and other qualities) over time through a distinction between determinables and determinates: an organism has the (determinable) temperature quality at all times; it has distinct (determinate) temperature qualities (for example: warm temperature, cold temperature) at distinct times.

In its treatment of attributes, BFO distinguishes between dispositions, which are internally grounded realizable entities (for example a skill or a tendency to baldness), and roles, which are externally grounded realizable entities (for example the lawyer role or the employee role, grounded in ascriptions by legal authorities or employers). Roles in this sense are always optional, in the sense that the bearer can in principle lose its role without thereby being physically changed.

4.9.6 Parts, wholes, unity and boundaries

BFO defines distinct relations of parthood for continuants and for occurrents.

BFO includes a distinction between objects and object aggregates, viewing the latter as exact sums of the former; however, it includes no axioms governing the summation of parts in general.

BFO deals with the factor of unity in its treatment of objects, where three sorts of unity are described – of connected portions of matter, of organisms, and of artefacts. This list is not, however, asserted to be exhaustive, and in addition to objects, fiat object parts and object aggregates, material entities might comprehend also portions of liquid, plasma and gas.

4.9.7 Space and place

Locations are represented by BFO in two ways: on the one hand by sites (for instance a graveyard, the interior of a room, the hull of a ship); on the other hand, by spatial regions (for instance as defined by latitude and longitude). Sites occupy spatial regions. They are not identical to spatial regions, since a site, for example Paris, can grow in size. Like spatial regions, sites are immaterial independent continuant entities.

The shapes of objects are qualities. BFO itself does not incorporate a treatment of the geometry of shapes.

4.9.8 Scale and granularity

BFO is an ontology that supports domain ontologies reflecting different perspectives on reality, including perspectives associated with different granularities (for example, in biology, of molecules, cells, organs, organisms and populations). Objects or processes on any given level of granularity are parts of objects on higher levels of granularity.

4.9.9 Qualities and other attributes

BFO recognizes qualities, dispositions and roles as entities that stand in the relation of specific dependence to their bearers; the redness of a rose is an instance of the quality red, which is a subtype of the quality colour; the disposition of this rose to wilt is an instance of the disposition: to wilt, which is a subtype of disposition.

BFO does not recognize attributes of attributes.

4.9.10 Quantities and mathematical entities

Quantities such as: length of 4 cm, or: temperature of 63 °C are subtypes of the corresponding qualities of length and temperature.

Entities, for BFO, exist either as universals or as instances of such universals, where instances are particulars existing in space and in time. Relations such as is_a and instance_of are thus not entities in BFO terms, since there are no instances of, for example, is_a.

There are, similarly, no instances in the realm of mathematics, and so also there are no mathematical entities in the BFO sense of 'entity'. Rather, mathematical theories are viewed by BFO as resources external to the ontology. BFO therefore does not incorporate a sub-ontology of mathematical entities treated in the abstract, that is to say as entities in their own right. Rather, in keeping with its purpose of promoting information sharing between different communities (for example of scientists engaging in experimental research), it treats entities such as units of measure, measurement data and mathematical formulae as information artefacts falling within the domain of the BFO-conforming Information Artefact Ontology (IAO).

4.9.11 Processes and events

Examples of processes in BFO include: processes of motion (location change); quality change; and processes of gaining and losing parts. BFO does not recognize a separate category of attributes of processes; rather, process attributions are treated using the machinery of defined classes (see 4.8.2.4). To make an assertion to the effect that an event is on-going is from the BFO perspective to assert that the event is occurring simultaneously with the making of the assertion.

BFO does not recognize a category of states (as in ‘state of pregnancy’, ‘state of being on’ of a light switch). Data pertaining to states of these and other sorts are dealt with in terms of defined classes.

4.9.12 Constitution

BFO identifies material entities and the material of which they are made at any given time. Thus, for such entities there is no distinction between constitution and identity.

As a domain-neutral ontology, BFO does not contain assertions about persons or organizations. One view conforming to BFO regards a person as identical with a certain organism (for a certain period in the history of the organism) and this in turn is regarded as identical with a certain material entity. An organization, on such a view, is regarded as identical with the totality of its members at any given time, whereby these members will at relevant times have specific organizational roles (duties and responsibilities) specific to this organization.

4.9.13 Causality

BFO treats causality under two headings: of causal unity of objects, and of processes triggering dispositions; BFO rests on the view that an exhaustive account of causal relations is possible only by combining BFO with domain ontologies in areas such as physics and biology.

4.9.14 Information and reference

The Information Artefact Ontology (IAO) has been developed as a BFO-conforming treatment of information entities, which form a subclass of what BFO calls generically dependent continuants. This means, in first approximation, that they are copyable patterns.

IAO introduces a relation of aboutness to connect information entities to the portions of reality to which they refer. IAO deals with cases of aboutness where there is no actual entity which a given information entity is about by pointing to the ways in which information entities feature as parts of larger systems in which references to actual entities are secured, for example when an engineering design features as part of a larger system incorporating information about shapes, materials, material processing, and so forth. The design stands in the relation of aboutness to the latter entities, even if it is never used as the basis for the production of a corresponding artefact.

4.9.15 Artefacts and socially constructed entities

Engineered items and other material artefacts can be defined in terms of the BFO categories of material entity and function. Dollar bills are examples of material artefacts, as are screwdrivers and defibrillators. They are material entities created to perform a certain function.

BFO as a domain-neutral ontology has no specific category covering socially constructed objects. An example of a BFO-conforming treatment of such entities is a view of contracts under the heading of information entities – for example conceiving an employment contract as an information entity describing certain roles and duties.

4.9.16 Mental entities; imagined entities; fiction; mythology; religion

Mental entities are dealt with through BFO-conforming extension ontologies such as the Mental Functioning Ontology,[5] which deals also with the phenomenon of imagination. As concerns entities in domains such as fiction, mythology and religion, BFO provides two alternative and mutually supportive approaches.

On the one hand it provides resources for dealing with the textual, psychological and social entities, data about which are collected by scientists when studying these domains. In the case of religion, for example, the BFO framework allows terms to be defined for entities such as prayers and religious texts within the Information Artefact Ontology. Religious beliefs and practices are dealt with in terms of dispositions of individuals and groups.

On the other hand, the BFO framework allows the development of what might be called ‘conditional’ or ‘provisional’ ontologies, designed to represent for example entities in fictional or mythological worlds in ways parallel to the ways in which more established scientific ontologies are used to represent entities in domains of physics or biology. Conditional ontologies stand out, however, in that the terms they contain are treated in such a way that ontological commitment is not presupposed. When a researcher counts the number of Gods in the Hellenic pantheon, for example, no assumption is made that the entities in question exist.

4.10 Documentation of ontology management principles (in conformance with 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/mara.

BFO is managed in accordance with the OBO Foundry management principles provided in Reference [9].

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