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CLIF as an Educational Tool for Teaching Realism-Based Ontology

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Why? (reason)

- My frustration with:
  - Inappropriate reference to BFO in 'ontology' work described in the literature,
  - OWL too much used as an exchange format rather than a language with formal semantics,
  - Existing tools make it too easy to:
    - make something that looks like an ontology (e.g. Protégé)
    - re-use content from something that looks like an ontology (e.g. Robot)
  - Students in my 700-level classes still making basic mistakes re BFO-principles,
  - …

Why? (purpose)

- Making it easier to grasp what BFO really says about reality
  - Way less, and more, than I thought!
- Improving quality of ontology design by using FOL as a basis:
  - Detecting inconsistencies
  - Identifying unintended consequences
- Improving quality of information systems, especially electronic healthcare records and repositories.
  - Leveraging Referent Tracking.

ISO/IEC 24707:2018

Information technology — Common Logic (CL) — A framework for a family of logic-based languages

Abstract

Preview

This document specifies a family of logic languages designed for use in the representation and interchange of information and data among disparate computer systems.

The following features are essential to the design of this document.

— Languages in the family have declarative semantics. It is possible to understand the meaning of expressions in these languages without appeal to an interpreter for manipulating those expressions.

— Languages in the family are logically comprehensive ? at its most general, they provide for the expression of arbitrary first-order logical sentences.

— Languages in the family are translatable by a semantics-preserving transformation to a common XML-based syntax, facilitating interchange of information among heterogeneous computer systems.

The following are within the scope of this document:

— representation of information in ontologies and knowledge bases;

— specification of expressions that are the input or output of inference engines;

— formal interpretations of the symbols in the language.

https://www.iso.org/standard/66249.html

Annex A
(normative)

Common Logic Interchange Format (CLIF)

A.1 General

Historically, the Common Logic project arose from an effort to update and rationalize the design of KIF[3] which was first proposed as a "knowledge interchange format" over a decade ago and, in a simplified form, has become a *de facto* standard notation in many applications of logic. Several features of Common Logic, most notably its use of sequence markers, are explicitly borrowed from KIF. However, the design philosophy of Common Logic differs from that of KIF in various ways, which is briefly reviewed here.

First, the goals of the languages are different. KIF was intended to be a common notation into which a variety of other languages could be translated without loss of meaning. Common Logic is intended to be used for information interchange over a network, as far as possible without requiring any translation to be done, and when it shall be done, Common Logic provides a single common *semantic* framework, rather than a syntactically defined interlingua.

BFO2020 axiomatization in CLIF

- Uses only parts of the CLIF specifications.
- Expressed in FOL with as important features:
  - use of equality,
  - (1-,) 2-, and 3-ary predicates,
  - no functions,
  - standard connectives
    - OR, AND, IF, IFF, NOT
  - universal and existential quantification
    - FORALL, EXISTS
  - ‘Realism-based’ choice of predicates.

'Realism-based' predicates

- Criteria:
  - Restricted to formal relations.
  - Grounded in the distinction between types (universals and defined classes) and particulars.
  - Use of temporal indexing.
- Example: 'all soccer balls are round'
  - FOL with properties 'fantologically conceived':
    - (forall (x) (if (soccer-ball x) (round x)))
  - Realism-based:
    - (forall (x t)
      (if (instance-of x soccer-ball t)
      (exists (y)
      (and (instance-of y round t)
      (inheres-in y x)))))

http://ontology.buffalo.edu/bfo/Against_Fantology.pdf

Deflated soccer balls are not round

- No problem for fantologists:
  - (forall (x) (if (deflated-soccer-ball x)
    (not-round x)))
- For realism-based ontologists:
  - One should not cram everything together in a predicate
  - Explicit time-indexing draws attention to issues of generalization
  - …
- Trying to adhere to realism-based principles requires thinking beyond applying logic.

https://soccerlifestyle.com/how-to-deflate-a-soccer-ball/

CLIF example
BFO2020's continuant-mereology.cl

```
(cl:comment 'BFO 2020 Axiomatization, generated 2021/11/12
    The most current version of this file will always be at the GitHub repository
    https://github.com/bfo-ontology/bfo-2020
    Author: Alan Ruttenberg - alanruttenberg@gmail.com
    This work is licensed under a Creative Commons "Attribution 4.0 International" license:
    https://creativecommons.org/licenses/by/4.0/'

    (cl:text
        (cl:ttl https://basic-formal-ontology.org/2020/formulas/clif/continuant-mereology.cl
          (cl:outdiscourse temporal-part-of exists-at has-proper-continuant-part
                          proper-continuant-part-of instance-of has-continuant-part continuant-part-of)

          (cl:comment "continuant-part-of and has-continuant-part are inverse relations [eld-1]"
             (forall (t a b)     (iff (continuant-part-of a b t) (has-continuant-part b a t))))

          (cl:comment "continuant-part-of is reflexive at a time [mcd-1]"
             (forall (a t) (if (instance-of a independent-continuant t) (continuant-part-of a a t))))
          ...
)))
```

Educational tools to train logical AND ontological thinking

- For working with BFO2020-style CLIF:
  - BFO2020-style CLIF template,
  - BFO2020-style CLIF parser with:
    - Various error-checking functions,
    - Warnings,
    - Tracking ontology-dependencies,
    - Conversion to various formats.
      - CLIF → CNF → CF → Kowalski rules
- Kowalski-rule-based reasoner:
  - Consistency checking for fact-based scenarios,
  - Predicate derivation.

'BFO2020-style' CLIF template

```
(cl:comment
    " SOMETEXT
    "
    (cl:text
        (cl:ttl "SOMETEXT"
                (cl:outdiscourse PREDICATE-NAMES
                )
                (cl:comment "SOMETEXT"
                        ( ...CLAUSE...)
                )
)))
```

Commented version

'BFO2020-style' CLIF parser demo

- Configurable behavior
  - Parser initialization file
- Parsing example:
  - Input:
    - All BFO2020 CLIF files except temporalized relations
    - OGMS mockup file
    - Tumor ontology mockup file
  - Parsing
  - Some notable output:
    - Comments / errors
    - Vocabulary used
    - Kowalski-rule base

5 forms of Kowalski rules

- ‘if-then’-rules:
  - (A & B & …) → P
  - true → P
- ‘if-then-or’-rules:
  - (A & B & …) → (P v Q v …)
  - true → (P v Q v …)
- ‘false-hood’-rules:
  - (A & B & …) → false

'BFO2020-style' CLIF reasoner current reasoning modes (1)

ont = defined in ontology

mpp = modus ponendo ponens:

A (...& ...) → B

A (...& ...)

B

mpt = modus ponendo tollens:

(A & ...) & B → false

(A & ...)

---

not B

'BFO2020-style' CLIF reasoner current reasoning modes (2)

mtt = modus tollendo tollens:

A → B

not B

---

not A

A & B & C → D

not D

A

B

---

not C

mtp = modus tollendo ponens:

A → B v C

A

not B

C

---

alternative generation

A → B v C

A

B v C

'BFO2020-style' CLIF reasoner current reasoning modes (4)

Reductio ad absurdum:

rana = ra with negative assumption

B v C

assume not B

---

inconsistent → B

---

rapa = ra with positive assumption

B v C

assume B

---

inconsistent → not B

repl: replicate

fact with A

A = B

---

fact with B

'BFO2020-style' CLIF reasoner current reasoning modes (3)

- Computing undeniables from remaining alternatives ...
  - mtpa: mtp on alternatives

    (B v C v D) & not B & not D → C
  - tapw: true in all possible worlds
    - Process one by one all instantiated rule R of form: 'true → A v B v …'
    - Assume each consequent of R to be true in its own possible world and further inference using proven facts from the base world and the specific possible world
    - Processing in a possible world stops when either
      - inconsistency derived, → assumed alternative false in the base world
      - If no further facts can be derived, evaluate all possible worlds (PW) for R
        - *if all PW inconsistent: then either the set of axioms is inconsistent or the input facts*
        - *if all but one possible worlds leads to an inconsistency: then the orginal assumption for that one world is true in the base world as well as all derivations made*
        - *if at least two PW not inconsistent: the derivations which are exactly similar in all PW are true in the base world. The original assumptions for these PW are then NOT proven.*

Why possible worlds? Some very odd conversions, eg [ild-1]

(cl:comment "participates-in is time indexed and has domain: independent-continuant but not spatial-region or specifically-dependent-continuant or generically-dependent-continuant and range: process [ild-1]"

```
(forall (a b t)
        (if (participates-in a b t)
            (and   (or     (and (instance-of a independent-continuant t)
                                (not (instance-of a spatial-region t)))
                           (instance-of a specifically-dependent-continuant t)
                           (instance-of a generically-dependent-continuant t))
                   (instance-of b process t)
                   (instance-of t temporal-region t)))))
```

'or' here reads as XOR but is not XOR!

ILD-1 generates 4 rules

If([participates-in,A,B,C]) →
then_or([[instance-of,A,generically-dependent-continuant,C],
[instance-of,A,independent-continuant,C],
[instance-of,A,specifically-dependent-continuant,C]]).

if([[instance-of,A,spatial-region,C],
[participates-in,A,B,C]]) →
then_or([[instance-of,A,generically-dependent-continuant,C],
[instance-of,A,specifically-dependent-continuant,C]]).

if([participates-in,A,B,C]),then([instance-of,C,temporal-region,C]).

if([participates-in,A,B,C]),then([instance-of,B,process,C]).

'BFO2020-style' CLIF reasoner demo

- Input:
  - Reasoner initialization file
  - Kowalski-rule base
  - Specific rendering of the first-order part of a minimalist Referent Tracking representation
- Reasoning:
  - Inconsistent input example
    - Invoke reasoner
    - Some output: inconsistency proof
  - Consistent input example
    - Invoke reasoner
    - Some output: derivations, alternatives, skolem table
      - Highlighted output table

To do

- Making tools fool-proof,
- Continue thorough debugging,
  - Three most common mistakes: boundary conditions and off-by-one,
- Better control of skolem functions,
- Creation of minimal models,
- Time lines,
- Parthood and type taxonomies
- Input queries
    - Current alternative: input the logical opposite of X, if inconsistency found → X is true
- CLIF style data input
  - E.g.: (not (exists (x) (instance-of tumor-of-john malignant-tumor x)))
- …

Parser initialization file

```
% INIT-file to parametrize the behavior of the BFO2020style-CLIFparser
% Parameters
%% projectname(string)     % OPTIONAL
                % Prefixes each output file with the provided string followed by '-'
                % If no valid projectname is provided, it will default to "ANONYMOUS"
projectname("TUMCASE-P").   % Set projectname to TUMCASE-P


%% ontology(string, stringlist) % REQUIRED
                % Identify specific files in <stringlist> as belonging to the ontology named in <string>
                % <stringlist> must be a list of strings in a format acceptable for filenames within the operating system
                % The ontology name will be used as prefix for axiom IDs provided in the CLIF files.
                %   For example, if the ontology name is "BFO", the axiom with index 'udu-1' will be prefixed as 'BFO-udu-1'.
                % Multiple occurrences allowed but no expanded filenames may overlap over distinct ontologies
ontology("BFO",["../BFO2020-corrected/*.cl"]).    % Declare all filenames with extention 'cl' as belonging to BFO
ontology("OGMS",["./OGMS-CLIF/ogms.cls"]).
ontology("TUM",["./TUMOR-CLIF/tumor.cls"]).


%% ont_uses(string, stringlist) % OPTIONAL
                % Declare the ontology with name in <string> as dependent on ontologies named in <stringlist>
ont_uses("OGMS",["BFO"]).
ont_uses("TUM",["OGMS","BFO"]).


%% skolem_mode(<atom>).      % REQUIRED
                % Sets how skolem constants and functions are generated
                %   scoped: standard way as function of which UQvars scoping EQvars are arguments
                %   mapped: as tokens expressed as either constants or variables as determined by variable_mode parameter
                %       produces a map of the tokens and what functions they are derived from  (not completely implemented yet)
                % BFO2020style-CLIFreasoner requires 'scoped'!
skolem_mode(scoped).      % set skolem_mode to scoped


%% variable_mode(unbound).   % REQUIRED
```

```
                % Sets the format of variables
                % options are: unbound, ground
variable_mode(unbound).       % options are: unbound, ground
progress_notification(minimal). % options are: minimal, verbose. 'verbose' is for debugging CLIF-files in case of parse-errors
minimum_constant_length(3).   % set minimum character length for non-outdiscourse constants. If omitted or non-integer
                %   given, defaults to 2.
typo_detection(0.95).       % level for approximate detection of term similarity to identify possible spelling mistakes.
                %   lower levels increase sensitivity at the cost of false positives
                %   higher levels decrease sensitivity at the cost of false negatives
                %   reasonable values are between 0.8 and 0.98
                %   defaults to 0.95 if omitted or unacceptable value provided
non_typo_display(3).        % possible typo's are detected on the basis of deviations from similar term with higher occurrence
                %   all occurrences of term suggestive of typo are displayed
                %   this setting shows also the occurrences of the non-typo term when it occurs less or equal than set
                %   default when non-set is 3
fixed_args(yes).        % specify whether predicates with same predicate name must have always the same number of arguments
                %   options are: yes, no.  Default is yes.
odd_pred_struc(5).          % threshold for displaying abnormal predicate structures. Default = 5.
rare_term_use(2).         % threshold for warning about terms used less or equal than number of times set. default = 2.
                %   these may be typo's without similarity to other terms, or terms with have little effect on reasoning.
missing_pred_percent(80).    % threshold to force warning about potentially missing predicate for constant in ontology as compared
                %   to other constants in the ontology, or an ontology which is used by the ontology.
                %   Default is 80, allowed values is between 0 (everything shown) to 100.

% Outputfiles to produce. Please comment out unneeded ones.
%outputfile(sci).          % sci = single condition implications
%outputfile(rules_per_axiom).   % rulebase representation sorted per axiom
outputfile(cnf).          % conjunctive normal form
outputfile(cf).           % clausal form
outputfile(kowalski).      % kowalski representation
outputfile(vocabulary).       % terms used in context
%outputfile(fol_formulae_s1). % original axioms with replaced implications and equivalence. Prolog list syntax.
```

OGMS mockup file

```
(cl:comment '
OGMS Axiomatization - mockup for demo purposes
Author: Werner Ceusters - wceusters@gmail.com
This work is licensed under a Creative Commons "Attribution 4.0 International" license:
https://creativecommons.org/licenses/by/4.0/'

 (cl:text

  (cl:ttl "OGMS mockup"

   (cl:outdiscourse instance-of universal)

  (cl:comment "disease is a universal [dise-uni]"
    (universal disease))

  (cl:comment "diseases are dispositions [dise-disp]"
    (forall (t x)
     (if (instance-of x disease t)
      (instance-of x disposition t))))

  (cl:comment "disorder is a universal [diso-uni]"
    (universal disorder))

  (cl:comment "disorders are material entities [diso-me]"
    (forall (t x)
     (if (instance-of x disorder t)
      (instance-of x material-entity t))))

)))
```

Tumor ontology mockup file

```
(cl:comment '
A few axioms about tumors
Author: Werner Ceusters - wceusters@gmail.com
This work is licensed under a Creative Commons "Attribution 4.0 International" license:
https://creativecommons.org/licenses/by/4.0/'

 (cl:text

  (cl:ttl "tumor axioms for demo-purposes"

   (cl:outdiscourse instance-of universal exists-at precedes)

  (cl:comment "cancer is a universal [can-uni]"
    (universal cancer))

  (cl:comment "cancers are diseases [can-dise]"
    (forall (t x)
     (if (instance-of x cancer t)
      (instance-of x disease t))))

  (cl:comment "tumor is a universal [tum-uni]"
    (universal tumor))

  (cl:comment "tumors are disorders of only two kinds: malignant or benign [tum-diso]"
    (forall (t x)
     (if (instance-of x tumor t)
    (and (instance-of x disorder t)
         (or (instance-of x benign-tumor t)
        (instance-of x malignant-tumor t))))))

  (cl:comment "benign tumors are tumors [btu-tum]"
    (forall (t x)
     (if (instance-of x benign-tumor t)
      (instance-of x tumor t))))

  (cl:comment "malignant tumors are tumors [mtu-tum]"
```

```
  (forall (t x)
   (if (instance-of x malignant-tumor t)
    (instance-of x tumor t))))

 (cl:comment "tumors cannot be malignant and benign at the same time [mtu-btu]"
    (not
  (exists (x t)
    (and (instance-of x benign-tumor t)
         (instance-of x malignant-tumor t)))))

 (cl:comment "tumors remain tumors as long as they exist [tum-perm1]"
  (forall (x)
   (if (exists (t) (instance-of x tumor t))
    (forall (t1)
     (if (exists-at x t1) (instance-of x tumor t1))))))

 (cl:comment "tumors exist during intervals [tum-perm2]"
  (forall (x t1 t2 t3)
   (if (and (instance-of x tumor t1)
         (exists-at x t3)
         (precedes t1 t2)
         (precedes t2 t3))
     (instance-of x tumor t2))))


)))
```

Comment file produced by parser (extract)

% WARNINGS

% Terms used less or equal than set in rare_term_use() in init-file:
% "cancer" used in:
% axiom 2 [TUM-can-dise] in file ./TUMOR-CLIF/tumor.cls
% axiom 1 [TUM-can-uni] in file ./TUMOR-CLIF/tumor.cls

% Axiom indices occurring in multiple axiom files:
% BFO-uns-1: [../BFO2020-corrected/continuant-mereology.cl,../BFO2020-corrected/existence-instantiation.cl]
% BFO-suk-1: [../BFO2020-corrected/order.cl,../BFO2020-corrected/temporal-region-corrected.cl]
% BFO-rzv-1: [../BFO2020-corrected/order.cl,../BFO2020-corrected/temporal-region-corrected.cl]
% BFO-qqv-1: [../BFO2020-corrected/order.cl,../BFO2020-corrected/temporal-region-corrected.cl]
% BFO-qnf-1: [../BFO2020-corrected/order.cl,../BFO2020-corrected/temporal-region-corrected.cl]
% BFO-qga-1: [../BFO2020-corrected/order.cl,../BFO2020-corrected/temporal-region-corrected.cl]
% BFO-qaf-1: [../BFO2020-corrected/existence-instantiation.cl,../BFO2020-corrected/temporal-region-corrected.cl]
% BFO-owb-1: [../BFO2020-corrected/order.cl,../BFO2020-corrected/temporal-region-corrected.cl]
% BFO-njq-1: [../BFO2020-corrected/temporal-region-corrected.cl,../BFO2020-corrected/universal-declaration.cl]
% BFO-miz-1: [../BFO2020-corrected/order.cl,../BFO2020-corrected/temporal-region-corrected.cl]
% BFO-fmm-1: [../BFO2020-corrected/generic-dependence.cl,../BFO2020-corrected/participation.cl]
% BFO-cgn-1: [../BFO2020-corrected/participation.cl,../BFO2020-corrected/specific-dependency.cl]
% BFO-adm-1: [../BFO2020-corrected/continuant-mereology.cl,../BFO2020-corrected/material-entity.cl]
% BFO-acg-1: [../BFO2020-corrected/order.cl,../BFO2020-corrected/temporal-region-corrected.cl]

% Axioms more than once included:
% <Axiom in clause form>
% <Axiom ID> / <Unique ID>
% [forall,[D,E,F],[or,[or,[not,[participates-in,D,E,F]],[not,[instance-of,D,generically-dependent-continuant,F]]],[exists,[B,C],[and,[temporal-part-of,B,F],[concretizes,C,D,B],[or,[and,[instance-of,C,specifically-dependent-continuant,B],[exists,[A],[and,[specifically-depends-on,C,A],[participates-in,A,E,B]]]],[and,[occurrent-part-of,C,E],[exists-at,C,B]]]]]]]
% BFO-fmm-1 / 49
% BFO-fmm-1 / 113
% [forall,[C,D,E],[or,[or,[not,[participates-in,C,D,E]],[not,[instance-of,C,specifically-dependent-continuant,E]]],[exists,[A,B],[and,[instance-of,A,temporal-region,A],[temporal-part-of,A,E],[instance-of,B,independent-continuant,A],[not,[instance-of,B,spatial-region,A]],[specifically-depends-on,C,B],[participates-in,B,D,A]]]]]
% BFO-cgn-1 / 112

% BFO-cgn-1 / 180
% [forall,[C,D],[or,[or,[forall,[A],[or,[identical,A,C],[not,[continuant-part-of,A,C,D]]]],[not,[instance-of,C,material-entity,D]]],[exists,[B],[and,[not,[identical,B,C]],[continuant-part-of,B,C,D],[not,[instance-of,B,immaterial-entity,D]]]]]
% BFO-adm-1 / 27
% BFO-adm-1 / 67
% [forall,[B,C],[or,[or,[exists,[A],[and,[temporal-part-of,A,B],[temporal-part-of,A,C]]],[not,[instance-of,C,temporal-interval,C]],[not,[instance-of,B,temporal-interval,B]]],[or,[precedes,B,C],[precedes,C,B]]]
% BFO-owb-1 / 105
% BFO-owb-1 / 217
% [forall,[A,B,C,D],[or,[or,[not,[temporal-part-of,D,C]],[not,[instance-of,A,B,C]]],[instance-of,A,B,D]]]
% BFO-qaf-1 / 35
% BFO-qaf-1 / 194
% [forall,[A,B,C,D],[or,[or,[not,[precedes,C,D]],[not,[has-first-instant,B,D]],[not,[has-last-instant,A,C]]],[precedes,A,B]]]
% BFO-qqv-1 / 95
% BFO-qqv-1 / 200
% [forall,[A,B,C,D],[or,[or,[not,[identical,C,D]],[not,[has-first-instant,B,D]],[not,[has-last-instant,A,C]],[instance-of,B,temporal-instant,B],[instance-of,A,temporal-instant,A]],[precedes,A,B]]]
% BFO-suk-1 / 102
% BFO-suk-1 / 214
% [forall,[A,B,C,D],[or,[or,[identical,C,D],[not,[has-first-instant,B,D]],[not,[has-last-instant,A,C]],[not,[precedes,A,B]]],[precedes,C,D]]]
% BFO-miz-1 / 99
% BFO-miz-1 / 205
% [forall,[A,B,C],[or,[or,[not,[has-last-instant,A,C]],[not,[has-first-instant,A,B]],[instance-of,A,temporal-instant,A]],[precedes,B,C]]]
% BFO-rzv-1 / 98
% BFO-rzv-1 / 204
% [forall,[A,B,C],[or,[or,[not,[continuant-part-of,C,A,B]],[not,[exists-at,A,B]]],[exists-at,C,B]]]
% BFO-uns-1 / 4
% BFO-uns-1 / 34
% [forall,[A,B],[or,[or,[not,[instance-of,B,temporal-instant,B]],[not,[instance-of,A,temporal-instant,A]]],[or,[precedes,A,B],[precedes,B,A],[identical,A,B]]]]
% BFO-qnf-1 / 101
% BFO-qnf-1 / 210
% [forall,[A,B],[or,[or,[not,[has-last-instant,B,A]],[instance-of,B,temporal-instant,B],[not,[instance-of,B,temporal-region,B]],[not,[instance-of,A,temporal-instant,A]]],[and,[or,[temporal-part-of,A,B],[precedes,B,A]],[or,[not,[precedes,B,A]],[not,[temporal-part-of,A,B]]]]]]
% BFO-acg-1 / 103
% BFO-acg-1 / 215
% [forall,[A,B],[or,[or,[not,[has-first-instant,B,A]],[instance-of,B,temporal-instant,B],[not,[instance-of,B,temporal-region,B]],[not,[instance-of,A,temporal-instant,A]]],[and,[or,[temporal-part-of,A,B],[precedes,A,B]],[or,[not,[precedes,A,B]],[not,[temporal-part-of,A,B]]]]]]

% BFO-qga-1 / 104
% BFO-qga-1 / 216
% [forall,[A,B],[or,[not,[instance-of,A,temporal-region,B]],[temporal-part-of,B,A]]]
% BFO-njq-1 / 186
% BFO-njq-1 / 270

% PROCESSING INFORMATION
% Files Processed:
% <Unique ID>/<Order in axiom file>/<Comment>:

% 1. ../BFO2020-corrected/continuant-mereology.cl
% 1 / 1 / continuant-part-of and has-continuant-part are inverse relations [eld-1]
% 2 / 2 / continuant-part-of is reflexive at a time [mcd-1]
% 3 / 3 / proper-continuant-part-of and has-proper-continuant-part are inverse relations [hpm-1]
% 4 / 4 / exists-at is dissective on first argumentwhen it is a continuant [uns-1]
…
<OTHER BFO OUTPUT DELETED>
…
% 14. ./OGMS-CLIF/ogms.cls
% 333 / 1 / disease is a universal [dise-uni]
% 334 / 2 / diseases are dispositions [dise-disp]
% 335 / 3 / disorder is a universal [diso-uni]
% 336 / 4 / disorders are material entities [diso-me]

% 15. ./TUMOR-CLIF/tumor.cls
% 337 / 1 / cancer is a universal [can-uni]
% 338 / 2 / cancers are diseases [can-dise]
% 339 / 3 / tumor is a universal [tum-uni]
% 340 / 4 / tumors are disorders of only two kinds: malignant or benign [tum-diso]
% 341 / 5 / benign tumors are tumors [btu-tum]
% 342 / 6 / malignant tumors are tumors [mtu-tum]
% 343 / 7 / tumors cannot be malignant and benign at the same time [mtu-btu]
% 344 / 8 / tumors remain tumors as long as they exist [tum-perm1]
% 345 / 9 / tumors exist during intervals [tum-perm2]

Parser generated Kowalski rule base for tumor axioms (other 1268 rules from BFO2020 and OGMS mockup omitted)

```
% cancer is a universal [can-uni]
r(1269,0,[],[],"TUM-can-uni",kow(true,then([universal,cancer]))).

% cancers are diseases [can-dise]
r(1270,1,[],[],"TUM-can-dise",kow(if([[instance-of,B,cancer,A]]),then([instance-of,B,disease,A]))).

% tumor is a universal [tum-uni]
r(1271,0,[],[],"TUM-tum-uni",kow(true,then([universal,tumor]))).

% tumors are disorders of only two kinds: malignant or benign [tum-diso]
r(1272,1,[],[],"TUM-tum-diso",kow(if([[instance-of,B,tumor,A]]),then_or([[instance-of,B,benign-tumor,A],[instance-of,B,malignant-tumor,A]]))).
r(1273,1,[],[],"TUM-tum-diso",kow(if([[instance-of,B,tumor,A]]),then([instance-of,B,disorder,A]))).

% benign tumors are tumors [btu-tum]
r(1274,1,[],[],"TUM-btu-tum",kow(if([[instance-of,B,benign-tumor,A]]),then([instance-of,B,tumor,A]))).

% malignant tumors are tumors [mtu-tum]
r(1275,1,[],[],"TUM-mtu-tum",kow(if([[instance-of,B,malignant-tumor,A]]),then([instance-of,B,tumor,A]))).

% tumors cannot be malignant and benign at the same time [mtu-btu]
r(1276,2,[],[],"TUM-mtu-btu",kow(if([[instance-of,A,benign-tumor,B],[instance-of,A,malignant-tumor,B]]),false)).

% tumors remain tumors as long as they exist [tum-perm1]
r(1277,2,[],[],"TUM-tum-perm1",kow(if([[exists-at,C,B],[instance-of,C,tumor,A]]),then([instance-of,C,tumor,B]))).

% tumors exist during intervals [tum-perm2]
r(1278,4,[],[],"TUM-tum-perm2",kow(if([[exists-at,A,D],[instance-of,A,tumor,B],[precedes,B,C],[precedes,C,D]]),then([instance-of,A,tumor,C]))).
```

Reasoner initialization file

```
% Parameters
ontologies("*-kowalski.txt").    % Works only with kowalski files in format generated by BFO2020style-CLIFparser.cl
                    % will take as input all files ending with "-kowalski.txt"
inputdata("*-input.txt").  % should be in the 't-format' of the 'database' section as used in BMI714 'RTreasoning"
outputfiles("CLIFreasoner").% each outputfile will start with "CLIFreasoner-". If not specified, output defaults to "CLR-ANONYMOUS"
skolem_level(2).       % Set level of distinct skolem function embedding.
            % Start always with 2. When no inconsistencies, set to 3 and higher.
            % Processing time increases with higher levels, but inconsistencies
            % and useful entailments may be found at higher values.
            % If there are axioms which introduce multiple skolems in consequent, set number to max number of such introductions
sk_cycle_level(0).     % Set level of identical skolem function embedding. Default is 0.
max_ante_arg_matches(5).  % Apply modus ponens with specified number of matching facts per universally quantified antecedent argument.
            % If an if-then rule has n arguments and the parameter is set to m, and for each argument m matches are found,
            % m^n combinations result. If it overflows the stack during execution, increase stack size in reasoner, install more memory or use lower m.
            % Default is 5.
```

Inconsistent reasoner input example

t([true,instance-of, tumor-of-john, tumor, t1]).

t([false,instance-of, tumor-of-john, malignant-tumor, t2]).
t([true,precedes,t1,t2]).

t([true,instance-of, tumor-of-john, cancer, t3]).
t([true,precedes,t2,t3]).

Reasoner-produced inconsistency proof

450	ERROR	inconsistency				<--	655	BFO-cig-1	inc	268	269	
269	TRUE	instance-of	tumor-of-john	specifically-dependent-continuant	sk20	<--	646	BFO-hke-1	mpp	182	256	
268	TRUE	instance-of	tumor-of-john	independent-continuant	sk20	<--	639	BFO-otk-1	mpp	90	256	
256	TRUE	exists-at	tumor-of-john	sk20		<--	73	BFO-bee-1	mpp	212	255	132
255	TRUE	instance-of	sk20	temporal-region	sk20	<--	59	BFO-lqn-1	mpp	132		
212	TRUE	universal	continuant			<--	558	BFO-axs-1	ont			
182	TRUE	instance-of	tumor-of-john	specifically-dependent-continuant	t3	<--	623	BFO-qix-1	mpp	84		
132	TRUE	instance-of	tumor-of-john	continuant	sk20	<--	129	BFO-ilw-1	mpp	124		
124	TRUE	instance-of	tumor-of-john	independent-continuant	t1	<--	606	BFO-faf-1	mpp	26		
90	TRUE	instance-of	tumor-of-john	independent-continuant	t3	<--	606	BFO-faf-1	mpp	46		
84	TRUE	instance-of	tumor-of-john	realizable-entity	t3	<--	595	BFO-fxd-1	mpp	48		
48	TRUE	instance-of	tumor-of-john	disposition	t3	<--	1266	OGMS-dise-disp	mpp	12		
46	TRUE	instance-of	tumor-of-john	material-entity	t3	<--	635	BFO-opd-1	mpp	26	13	
26	TRUE	instance-of	tumor-of-john	material-entity	t1	<--	1268	OGMS-diso-me	mpp	20		
20	TRUE	instance-of	tumor-of-john	disorder	t1	<--	1273	TUM-tum-diso	mpp	1		
13	TRUE	exists-at	tumor-of-john	t3		<--	73	BFO-bee-1	mpp	10	9	4
12	TRUE	instance-of	tumor-of-john	disease	t3	<--	1270	TUM-can-dise	mpp	4		
10	TRUE	universal	cancer			<--	1269	TUM-can-uni	ont			
9	TRUE	instance-of	t3	temporal-region	t3	<--	59	BFO-lqn-1	mpp	4		
4	TRUE	instance-of	tumor-of-john	cancer	t3	<--	0	unmarked	input			
1	TRUE	instance-of	tumor-of-john	tumor	t1	<--	0	unmarked	input			

Consistent reasoner input example

t([true,instance-of, tumor-of-john, tumor, t1]).

t([false,instance-of, tumor-of-john, malignant-tumor, t2]).
t([true,precedes,t1,t2]).

t([true,instance-of, tumor-of-john, malignant-tumor, t3]).
t([true,precedes,t2,t3]).

Reasoner-produced positive derivations for consistent input data (relations amongst skolem constants omitted, sorted on first argument of predicate)

1290	TRUE	universal	benign-tumor			<--	60	BFO-lqn-1	mpp	1289		
197	TRUE	universal	continuant			<--	558	BFO-axs-1	ont			
23	TRUE	universal	disorder			<--	1267	OGMS-diso-uni	ont			
118	TRUE	universal	history			<--	552	BFO-gki-1	ont			
223	TRUE	universal	immaterial-entity			<--	569	BFO-zcc-1	ont			
123	TRUE	universal	independent-continuant			<--	574	BFO-ufw-1	ont			
10	TRUE	universal	malignant-tumor			<--	60	BFO-lqn-1	mpp	4		
80	TRUE	universal	material-entity			<--	563	BFO-hru-1	ont			
39	TRUE	universal	occurrent			<--	557	BFO-lkt-1	ont			
143	TRUE	universal	one-dimensional-temporal-region			<--	578	BFO-qar-1	ont			
201	TRUE	universal	process			<--	553	BFO-bsm-1	ont			
263	TRUE	universal	process-boundary			<--	567	BFO-zqv-1	ont			
134	TRUE	universal	spatial-region			<--	562	BFO-rej-1	ont			
108	TRUE	universal	spatiotemporal-region			<--	573	BFO-mdh-1	ont			
41	TRUE	entity	t1			<--	622	BFO-vgn-1	mpp	15		
42	TRUE	exists-at	t1	sk3		<--	73	BFO-bee-1	mpp	39	38	15
33	TRUE	exists-at	t1	t1		<--	73	BFO-bee-1	mpp	25	18	18
30	TRUE	has-first-instant	t1	sk7		<--	485	BFO-daf-1	mpp	18		
29	TRUE	has-last-instant	t1	sk6		<--	484	BFO-daf-1	mpp	18		
87	TRUE	has-occurrent-part	t1	t1		<--	147	BFO-yvi-1	mpp	40		
106	TRUE	has-temporal-part	t1	t1		<--	462	BFO-boo-1	mpp	28		
88	TRUE	identical	t1	t1		<--	152	BFO-xlu-1	mpp	40	40	
15	TRUE	instance-of	t1	occurrent	sk3	<--	214	BFO-sen-1	mpp	3		
32	TRUE	instance-of	t1	occurrent	t1	<--	591	BFO-ejl-1	mpp	18		
18	TRUE	instance-of	t1	temporal-region	t1	<--	59	BFO-lqn-1	mpp	1		
40	TRUE	occurrent-part-of	t1	t1		<--	151	BFO-hbj-1	mpp	15		
22	TRUE	particular	t1			<--	57	BFO-oap-1	mpp	21		
149	TRUE	precedes	t1	sk15		<--	238	BFO-wff-1	mpp	94	3	88
158	TRUE	precedes	t1	sk9		<--	238	BFO-wff-1	mpp	46	16	88
3	TRUE	precedes	t1	t2		<--	0	unmarked	input			
16	TRUE	precedes	t1	t3		<--	211	BFO-ctz-1	mpp	5	3	
28	TRUE	temporal-part-of	t1	t1		<--	467	BFO-njq-1	mpp	18		

56	TRUE	entity	t2			<--	622	BFO-vgn-1	mpp	8		
57	TRUE	exists-at	t2	sk2		<--	73	BFO-bee-1	mpp	39	52	8
98	TRUE	exists-at	t2	t2		<--	73	BFO-bee-1	mpp	25	34	34
96	TRUE	has-first-instant	t2	sk17		<--	485	BFO-daf-1	mpp	34		
95	TRUE	has-last-instant	t2	sk16		<--	484	BFO-daf-1	mpp	34		
71	TRUE	has-occurrent-part	t2	t2		<--	147	BFO-yvi-1	mpp	54		
69	TRUE	has-temporal-part	t2	t2		<--	462	BFO-boo-1	mpp	55		
70	TRUE	identical	t2	t2		<--	469	BFO-zdq-1	mpp	55	55	
8	TRUE	instance-of	t2	occurrent	sk2	<--	214	BFO-sen-1	mpp	5		
97	TRUE	instance-of	t2	occurrent	t2	<--	591	BFO-ejl-1	mpp	34		
34	TRUE	instance-of	t2	temporal-region	t2	<--	59	BFO-lqn-1	mpp	17		
54	TRUE	occurrent-part-of	t2	t2		<--	151	BFO-hbj-1	mpp	8		
53	TRUE	particular	t2			<--	61	BFO-lqn-1	mpp	8		
126	TRUE	preceded-by	t2	sk4		<--	208	BFO-tib-1	mpp	115		
14	TRUE	preceded-by	t2	t1		<--	208	BFO-tib-1	mpp	3		
79	TRUE	precedes	t2	sk9		<--	238	BFO-wff-1	mpp	46	5	70
5	TRUE	precedes	t2	t3		<--	0	unmarked	input			
55	TRUE	temporal-part-of	t2	t2		<--	468	BFO-bvr-1	mpp	8		
60	TRUE	entity	t3			<--	622	BFO-vgn-1	mpp	7		
61	TRUE	exists-at	t3	sk1		<--	73	BFO-bee-1	mpp	39	58	7
51	TRUE	exists-at	t3	t3		<--	73	BFO-bee-1	mpp	25	9	9
49	TRUE	has-first-instant	t3	sk11		<--	485	BFO-daf-1	mpp	9		
337	TRUE	has-first-instant	t3	sk12		<--	-3	identity	repl	49	333	
48	TRUE	has-last-instant	t3	sk10		<--	484	BFO-daf-1	mpp	9		
63	TRUE	has-occurrent-part	t3	t3		<--	147	BFO-yvi-1	mpp	59		
78	TRUE	has-temporal-part	t3	t3		<--	462	BFO-boo-1	mpp	47		
64	TRUE	identical	t3	t3		<--	152	BFO-xlu-1	mpp	59	59	
7	TRUE	instance-of	t3	occurrent	sk1	<--	213	BFO-sen-1	mpp	5		
50	TRUE	instance-of	t3	occurrent	t3	<--	591	BFO-ejl-1	mpp	9		
9	TRUE	instance-of	t3	temporal-region	t3	<--	59	BFO-lqn-1	mpp	4		
59	TRUE	occurrent-part-of	t3	t3		<--	151	BFO-hbj-1	mpp	7		
43	TRUE	particular	t3			<--	57	BFO-oap-1	mpp	13		
211	TRUE	preceded-by	t3	sk15		<--	208	BFO-tib-1	mpp	148		
128	TRUE	preceded-by	t3	sk4		<--	208	BFO-tib-1	mpp	114		
37	TRUE	preceded-by	t3	t1		<--	208	BFO-tib-1	mpp	16		
6	TRUE	preceded-by	t3	t2		<--	208	BFO-tib-1	mpp	5		

47	TRUE	temporal-part-of	t3	t3		<--	467	BFO-njq-1	mpp	9			
172	TRUE	universal	temporal-instant			<--	568	BFO-bjs-1	ont				
100	TRUE	universal	temporal-interval			<--	571	BFO-kuz-1	ont				
25	TRUE	universal	temporal-region			<--	564	BFO-toj-1	ont				
225	TRUE	universal	three-dimensional-spatial-region			<--	581	BFO-qov-1	ont				
19	TRUE	universal	tumor			<--	1271	TUM-tum-uni	ont				
309	TRUE	continuant-part-of	tumor-of-john	tumor-of-john	sk20	<--	3	BFO-mcd-1	mpp	246			
1299	TRUE	continuant-part-of	tumor-of-john	tumor-of-john	sk43	<--	3	BFO-mcd-1	mpp	1298			
16644	TRUE	continuant-part-of	tumor-of-john	tumor-of-john	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362	
122	TRUE	continuant-part-of	tumor-of-john	tumor-of-john	t1	<--	3	BFO-mcd-1	mpp	116			
150	TRUE	continuant-part-of	tumor-of-john	tumor-of-john	t2	<--	3	BFO-mcd-1	mpp	93			
162	TRUE	continuant-part-of	tumor-of-john	tumor-of-john	t3	<--	3	BFO-mcd-1	mpp	83			
198	TRUE	entity	tumor-of-john			<--	621	BFO-vgn-1	mpp	163			
237	TRUE	exists-at	tumor-of-john	sk20		<--	73	BFO-bee-1	mpp	197	236	124	
1301	TRUE	exists-at	tumor-of-john	sk43		<--	73	BFO-bee-1	mpp	123	1296	1298	
16646	TRUE	exists-at	tumor-of-john	sk53		<--	300	BFO-grv-1	tapw	1297	1298	1362	
21	TRUE	exists-at	tumor-of-john	t1		<--	73	BFO-bee-1	mpp	19	18	1	
36	TRUE	exists-at	tumor-of-john	t2		<--	73	BFO-bee-1	mpp	19	34	17	
13	TRUE	exists-at	tumor-of-john	t3		<--	73	BFO-bee-1	mpp	10	9	4	
318	TRUE	has-continuant-part	tumor-of-john	tumor-of-john	sk20	<--	1	BFO-eld-1	mpp	309			
1317	TRUE	has-continuant-part	tumor-of-john	tumor-of-john	sk43	<--	1	BFO-eld-1	mpp	1299			
16650	TRUE	has-continuant-part	tumor-of-john	tumor-of-john	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362	
238	TRUE	has-continuant-part	tumor-of-john	tumor-of-john	t1	<--	1	BFO-eld-1	mpp	122			
209	TRUE	has-continuant-part	tumor-of-john	tumor-of-john	t2	<--	1	BFO-eld-1	mpp	150			
199	TRUE	has-continuant-part	tumor-of-john	tumor-of-john	t3	<--	1	BFO-eld-1	mpp	162			
164	TRUE	has-history	tumor-of-john	sk14		<--	100	BFO-abx-1	mpp	82			
2224	TRUE	identical	tumor-of-john	tumor-of-john		<--	48	BFO-fyf-1	rana	9	162	163	
1289	TRUE	instance-of	tumor-of-john	benign-tumor	t2	<--	1272	TUM-tum-diso	mtp	2	17		
124	TRUE	instance-of	tumor-of-john	continuant	sk20	<--	129	BFO-ilw-1	mpp	116			
1300	TRUE	instance-of	tumor-of-john	continuant	sk43	<--	601	BFO-wyq-1	mpp	1298			
16645	TRUE	instance-of	tumor-of-john	continuant	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362	
125	TRUE	instance-of	tumor-of-john	continuant	t1	<--	601	BFO-wyq-1	mpp	116			
151	TRUE	instance-of	tumor-of-john	continuant	t2	<--	601	BFO-wyq-1	mpp	93			
163	TRUE	instance-of	tumor-of-john	continuant	t3	<--	601	BFO-wyq-1	mpp	83			
308	TRUE	instance-of	tumor-of-john	disorder	sk20	<--	1273	TUM-tum-diso	mpp	247			
1318	TRUE	instance-of	tumor-of-john	disorder	sk43	<--	1273	TUM-tum-diso	mpp	1316			

16651	TRUE	instance-of	tumor-of-john	disorder	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362	
20	TRUE	instance-of	tumor-of-john	disorder	t1	<--	1273	TUM-tum-diso	mpp	1			
35	TRUE	instance-of	tumor-of-john	disorder	t2	<--	1273	TUM-tum-diso	mpp	17			
45	TRUE	instance-of	tumor-of-john	disorder	t3	<--	1273	TUM-tum-diso	mpp	12			
246	TRUE	instance-of	tumor-of-john	independent-continuant	sk20	<--	639	BFO-otk-1	mpp	83	237		
1298	TRUE	instance-of	tumor-of-john	independent-continuant	sk43	<--	287	BFO-lzw-1	mpp	1292			
16643	TRUE	instance-of	tumor-of-john	independent-continuant	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362	
116	TRUE	instance-of	tumor-of-john	independent-continuant	t1	<--	606	BFO-faf-1	mpp	24			
93	TRUE	instance-of	tumor-of-john	independent-continuant	t2	<--	639	BFO-otk-1	mpp	83	36		
83	TRUE	instance-of	tumor-of-john	independent-continuant	t3	<--	606	BFO-faf-1	mpp	44			
4	TRUE	instance-of	tumor-of-john	malignant-tumor	t3	<--	0	unmarked	input				
245	TRUE	instance-of	tumor-of-john	material-entity	sk20	<--	635	BFO-opd-1	mpp	44	237		
1315	TRUE	instance-of	tumor-of-john	material-entity	sk43	<--	635	BFO-opd-1	mpp	245	1301		
16648	TRUE	instance-of	tumor-of-john	material-entity	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362	
24	TRUE	instance-of	tumor-of-john	material-entity	t1	<--	1268	OGMS-diso-me	mpp	20			
84	TRUE	instance-of	tumor-of-john	material-entity	t2	<--	635	BFO-opd-1	mpp	44	36		
44	TRUE	instance-of	tumor-of-john	material-entity	t3	<--	635	BFO-opd-1	mpp	24	13		
247	TRUE	instance-of	tumor-of-john	tumor	sk20	<--	1277	TUM-tum-perm1	mpp	12	237		
1316	TRUE	instance-of	tumor-of-john	tumor	sk43	<--	1277	TUM-tum-perm1	mpp	247	1301		
16649	TRUE	instance-of	tumor-of-john	tumor	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362	
1	TRUE	instance-of	tumor-of-john	tumor	t1	<--	0	unmarked	input				
17	TRUE	instance-of	tumor-of-john	tumor	t2	<--	1278	TUM-tum-perm2	mpp	5	3	1	13
12	TRUE	instance-of	tumor-of-john	tumor	t3	<--	1275	TUM-mtu-tum	mpp	4			
1284	TRUE	located-in	tumor-of-john	tumor-of-john	sk20	<--	289	BFO-bao-1	mtp	246	309	1183	
1521	TRUE	located-in	tumor-of-john	tumor-of-john	sk43	<--	289	BFO-bao-1	mtp	1298	1299	1362	
16691	TRUE	located-in	tumor-of-john	tumor-of-john	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362	
1288	TRUE	located-in	tumor-of-john	tumor-of-john	t1	<--	289	BFO-bao-1	mtp	116	122	878	
1287	TRUE	located-in	tumor-of-john	tumor-of-john	t2	<--	289	BFO-bao-1	mtp	93	150	941	
1285	TRUE	located-in	tumor-of-john	tumor-of-john	t3	<--	289	BFO-bao-1	mtp	83	162	962	
1295	TRUE	location-of	tumor-of-john	tumor-of-john	sk20	<--	258	BFO-kaw-1	mpp	1284			
1522	TRUE	location-of	tumor-of-john	tumor-of-john	sk43	<--	258	BFO-kaw-1	mpp	1521			
16692	TRUE	location-of	tumor-of-john	tumor-of-john	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362	
1291	TRUE	location-of	tumor-of-john	tumor-of-john	t1	<--	258	BFO-kaw-1	mpp	1288			
1293	TRUE	location-of	tumor-of-john	tumor-of-john	t2	<--	258	BFO-kaw-1	mpp	1287			
1294	TRUE	location-of	tumor-of-john	tumor-of-john	t3	<--	258	BFO-kaw-1	mpp	1285			
1292	TRUE	occupies-spatial-region	tumor-of-john	sk42	sk43	<--	279	BFO-uas-1	mpp	1288			

244	TRUE	participates-in	tumor-of-john	sk14	sk20	<--	106	BFO-lga-1	mpp	82	237	
1314	TRUE	participates-in	tumor-of-john	sk14	sk43	<--	106	BFO-lga-1	mpp	82	1301	
16647	TRUE	participates-in	tumor-of-john	sk14	sk53	<--	300	BFO-grv-1	tapw	1297	1298	1362
166	TRUE	participates-in	tumor-of-john	sk14	t1	<--	106	BFO-lga-1	mpp	82	21	
92	TRUE	participates-in	tumor-of-john	sk14	t2	<--	106	BFO-lga-1	mpp	82	36	
165	TRUE	participates-in	tumor-of-john	sk14	t3	<--	106	BFO-lga-1	mpp	82	13	
11	TRUE	particular	tumor-of-john			<--	61	BFO-lqn-1	mpp	4		
187	TRUE	universal	zero-dimensional-temporal-region			<--	582	BFO-bau-1	ont			

Reasoner-produced unsolved alternatives (extract)

[instance-of,tumor-of-john,benign-tumor,t1]
[instance-of,tumor-of-john,malignant-tumor,t1]

[instance-of,t2,one-dimensional-temporal-region,t2]
[instance-of,t2,zero-dimensional-temporal-region,t2]

[instance-of,t1,one-dimensional-temporal-region,t1]
[instance-of,t1,zero-dimensional-temporal-region,t1]

[instance-of,t3,one-dimensional-temporal-region,t3]
[instance-of,t3,zero-dimensional-temporal-region,t3]