# Getting Started:

## 1 OWL-RL

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## Python Module Index

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A simple implementation of the OWL2 RL Profile, as well as a basic RDFS inference, on top of RDFLib. Based on mechanical forward chaining. The distribution contains:

**OWL-RL**: the Python library. You should copy the directory somewhere into your `PYTHONPATH`. Alternatively, you can also run the `python setup.py install` script in the directory.

- `scripts/RDFConvertService`: can be used as a CGI script to invoke the library. It may have to be adapted to the local server setup.
- `scripts/owlrl`: script that can be run locally on to transform a file into RDF (on the standard output). Run the script with `-h` to get the available flags.

The package requires Python version 3.5 or higher; it depends on RDFLib; version 4.2.2 or higher is required. If you need the python 2.7.x compatible version, see the @/py2 branch in this repository.

For the details on RDFS, see the [RDF Semantics Specification](#); for OWL 2 RL, see the [OWL 2 Profile specification](#).

View the **OWL-RL documentation** online: [http://owl-rl.readthedocs.io/](http://owl-rl.readthedocs.io/)

To view the changelog for this software library, see `CHANGELOG.rst`.

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### 1.1 Installation

*Coming soon.*

### 1.2 Usage

*Coming soon.*
1.3 Indices and tables

- genindex
- modindex
- search

1.4 owlrl

This module is a brute force implementation of the ‘finite’ version of RDFS semantics and of OWL 2 RL on the top of RDFLib (with some caveats, see below). Some extensions to these are also implemented.

Brute force means that, in all cases, simple forward chaining rules are used to extend (recursively) the incoming graph with all triples that the rule sets permit (i.e., the “deductive closure” of the graph is computed). There is an extra option whether the axiomatic triples are added to the graph (prior to the forward chaining step). These, typically set the domain and range for properties or define some core classes. In the case of RDFS, the implementation uses a ‘finite’ version of the axiomatic triples only (as proposed, for example, by Herman ter Horst). This means that it adds only those rdf:_i type predicates that do appear in the original graph, thereby keeping this step finite. For OWL 2 RL, OWL 2 does not define axiomatic triples formally; but they can be deduced from the OWL 2 RDF Based Semantics document and are listed in Appendix 6 (though informally).

Note: This implementation adds only those triples that refer to OWL terms that are meaningful for the OWL 2 RL case.

1.4.1 Package Entry Points

The main entry point to the package is via the DeductiveClosure class. This class should be initialized to control the parameters of the deductive closure; the forward chaining is done via the L(expand<DeductiveClosure.expand>) method. The simplest way to use the package from an RDFLib application is as follows:

```python
graph = Graph() # creation of an RDFlib graph
... # normal RDFlib application, eg,
... # parsing RDF data
DeductiveClosure(OWLRL_Semantics).expand(graph) # calculate an OWL 2 RL deductive closure of graph
# without axiomatic triples
```

The first argument of the DeductiveClosure initialization can be replaced by other classes, providing different types of deductive closure; other arguments are also possible. For example:

```python
DeductiveClosure(OWLRL_Extension, rdfs_closure = True, axiomatic_triples = True, datatype_axioms = True).expand(graph)
```
This will calculate the deductive closure including RDFS and some extensions to OWL 2 RL, and with all possible axiomatic triples added to the graph (this is about the maximum the package can do...)

The same instance of `DeductiveClosure` can be used for several graph expansions. In other words, the expand function does not change any state.

For convenience, a second entry point to the package is provided in the form of a function called `convert_graph()`, that expects a directory with various options, including a file name. The function parses the file, creates the expanded graph, and serializes the result into RDF/XML or Turtle. This function is particularly useful as an entry point for a CGI call (where the HTML form parameters are in a directory) and is easy to use with a command line interface. The package distribution contains an example for both.

There are major closure type (ie, semantic closure possibilities); these can be controlled through the appropriate parameters of the `DeductiveClosure` class:

- using the `RDFS_Semantics` class, implementing the RDFS semantics.
- using the `OWLRL.OWLRL_Semantics` class, implementing the OWL 2 RL.
- using `CombinedClosure.RDFS_OWLRL_Semantics` class, implementing a combined semantics of RDFS semantics and OWL 2 RL.

In all three cases there are other dimensions that can control the exact closure being generated:

- for convenience, the so called axiomatic triples (see, eg, the axiomatic triples in RDFS are, by default, I{not} added to the graph closure to reduce the number of generated triples. These can be controlled through a separate initialization argument.
- similarly, the axiomatic triples for D-entailment are separated.

### 1.4.2 Some Technical/implementation aspects

The core processing is done in the in the `Closure.Core` class, which is subclassed by the `RDFSClosure.RDFS_Semantics` and the `OWLRL.OWLRL_Semantics` classes (these two are then, on their turn, subclassed by the `CombinedClosure.RDFS_OWLRL_Semantics` class). The core implements the core functionality of cycling through the rules, whereas the rules themselves are defined and implemented in the subclasses. There are also methods that are executed only once either at the beginning or at the end of the full processing cycle. Adding axiomatic triples is handled separately, which allows a finer user control over these features.

Literals must be handled separately. Indeed, the functionality relies on ‘extended’ RDF graphs, that allows literals to be in a subject position, too. Because RDFLib does not allow that, processing begins by exchanging all literals in the graph for bnodes (identical literals get the same associated bnode). Processing occurs on these bnodes; at the end of the process all these bnodes are replaced by their corresponding literals if possible (if the bnode occurs in a subject position, that triple is removed from the resulting graph). Details of this processing is handled in the separate `Literals.LiteralProxies` class.

The OWL specification includes references to datatypes that are not in the core RDFS specification, consequently not directly implemented by RDFLib. These are added in a separate module of the package.

### Problems with Literals with datatypes

The current distribution of RDFLib is fairly poor in handling datatypes, particularly in checking whether a lexical form of a literal is “proper” as for its declared datatype. A typical example is:

```
"-1234"^^xsd:nonNegativeInteger
```
which should not be accepted as valid literal. Because the requirements of OWL 2 RL are much stricter in this respect, an alternative set of datatype handling (essentially, conversions) had to be implemented (see the XsdDatatypes module).

The DeductiveClosure class has an additional instance variable whether the default RDFLib conversion routines should be exchanged against the new ones. If this flag is set to True and instance creation (this is the default), then the conversion routines are set back to the originals once the expansion is complete, thereby avoiding to influence older application that may not work properly with the new set of conversion routines.

If the user wants to use these alternative lexical conversions everywhere in the application, then the DeductiveClosure.use_improved_datatypes_conversions() method can be invoked. That method changes the conversion routines and, from that point on, all usage of DeductiveClosure instances will use the improved conversion methods without resetting them. I.e., the code structure can be something like:

```python
DeductiveClosure().use_improved_datatypes_conversions()
... RDFLib application
DeductiveClosure().expand(graph)
...
```

The default situation can be set back using the DeductiveClosure.use_rdflib_datatypes_conversions() call.

It is, however, not required to use these methods at all. I.e., the user can use:

```python
DeductiveClosure(improved_datatypes=False).expand(graph)
```

which will result in a proper graph expansion except for the datatype specific comparisons which will be incomplete.

Requires:

- RDFLib, 4.0.0 and higher.
- rdflib_jsonld

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Organization: World Wide Web Consortium

Author: Ivan Herman

class owlrl.DeductiveClosure(closure_class, improved_datatypes=True, rdfs_closure=False, axiomatic_triples=False, datatype_axioms=False)

Bases: object

Entry point to generate the deductive closure of a graph. The exact choice deductive closure is controlled by a class reference. The important initialization parameter is the closure_class, a Class object referring to a subclass of Closure.Core. Although this package includes a number of such subclasses OWLRL_Semantics, RDFS_Semantics, RDFS_OWLRL_Semantics, and OWLRL_Extension, the user can use his/her own if additional rules are implemented.

Note that owl:imports statements are not interpreted in this class, that has to be done beforehand on the graph that is to be expanded.

Parameters

- **closure_class** (subclass of Closure.Core) – A closure class reference.
- **improved_datatypes** (bool) – Whether the improved set of lexical-to-Python conversions should be used for datatype handling. See the introduction for more details. Default: True.
- **rdfs_closure** (bool) – Whether the RDFS closure should also be executed. Default: False.
• **axiomatic_triples** *(bool)* – Whether relevant axiomatic triples are added before chaining, except for datatype axiomatic triples. Default: False.

• **datatype_axioms** *(bool)* – Whether further datatype axiomatic triples are added to the output. Default: false.

**Variables** **improved_datatype_generic** – Whether the improved set of lexical-to-Python conversions should be used for datatype handling in general, i.e., not only for a particular instance and not only for inference purposes. Default: False.

**expand**(graph)
Expand the graph using forward chaining, and with the relevant closure type.

```python
Parameters

- **graph** *(rdflib.Graph)* – The RDF graph.
```

**improved_datatype_generic** = False

```python
static use_improved_datatypes_conversions()
Switch the system to use the improved datatype conversion routines.
```

```python
static use_rdflib_datatypes_conversions()
Switch the system to use the generic (RDFLib) datatype conversion routines
```

**owlrl**.**convert_graph**(options, closureClass=None)
Entry point for external scripts (CGI or command line) to parse an RDF file(s), possibly execute OWL and/or RDFS closures, and serialize back the result in some format.

Note that this entry point can be used requiring no entailment at all; because both the input and the output format for the package can be RDF/XML or Turtle, such usage would simply mean a format conversion.

If OWL 2 RL processing is required, that also means that the **owl:imports** statements are interpreted. I.e., ontologies can be spread over several files. Note, however, that the output of the process would then include all imported ontologies, too.

**Parameters**

- **options** *(object)* – Object with specific attributes.

  - **options.sources** *(list)* – List of uris or file names for the source data; for each one if the name ends with ‘ttl’, it is considered to be turtle, RDF/XML otherwise (this can be overwritten by the options.iformat, though)

  - **options.text** *(str)* – Direct Turtle encoding of a graph as a text string (useful, eg, for a CGI call using a text field).

  - **options.owlClosure** *(bool)* – Can be yes or no.

  - **options.rdfsClosure** *(bool)* – Can be yes or no.

  - **options.owlExtras** *(bool)* – Can be yes or no; whether the extra rules beyond OWL 2 RL are used or not.

  - **options.axioms** *(bool)* – Whether relevant axiomatic triples are added before chaining (can be a boolean, or the strings “yes” or “no”).

  - **options.daxioms** *(bool)* – Further datatype axiomatic triples are added to the output (can be a boolean, or the strings “yes” or “no”).

  - **options.format** *(str)* – Output format, can be “turtle” or “rdfxml”.

  - **options.iformat** *(str)* – Input format, can be “turtle”, “rdfa”, “json”, “rdfxml”, or “auto”. “auto” means that the suffix of the file is considered: ‘.ttl’, ‘.html’, ‘json’ or ‘.jsonld’ respectively with ‘xml’ as a fallback.
• **options.trimming** *(bool)* – Whether the extension to OWLRL should also include trimming.

• **closureClass** *(TODO(edmond.chuc@csiro.au): What class is this supposed to be?)* – Explicit class reference. If set, this overrides the various different other options to be used as an extension.

**owlrl.interpret_owl_imports**(iformat, graph)

Interpret the owl import statements. Essentially, recursively merge with all the objects in the owl import statement, and remove the corresponding triples from the graph.

This method can be used by an application prior to expansion. It is not done by the DeductiveClosure class.

**Parameters**

- iformat *(str)* – Input format; can be one of AUTO, TURTLE, or RDFXML. AUTO means that the suffix of the file name or URI will decide: `.ttl` means Turtle, RDF/XML otherwise.

- graph *(RDFLib.Graph)* – The RDFLib Graph instance to parse into.

**owlrl.return_closure_class**(owl_closure, rdfs_closure, owl_extras, trimming=False)

Return the right semantic extension class based on three possible choices (this method is here to help potential users, the result can be fed into a DeductiveClosure instance at initialization).

**Parameters**

- **owl_closure** *(bool)* – Whether OWL 2 RL deductive closure should be calculated.

- **rdfs_closure** *(bool)* – Whether RDFS deductive closure should be calculated. In case owl_closure==True, this parameter should also be used in the initialization of DeductiveClosure.

- **owl_extras** *(bool)* – Whether the extra possibilities (rational datatype, etc) should be added to an OWL 2 RL deductive closure. This parameter has no effect in case owl_closure==False.

- **trimming** *(bool)* – Whether extra trimming is done on the OWL RL + Extension output.

**Returns** Deductive class reference or None.

**Return type** DeductiveClosure or None

### 1.5 AxiomaticTriples

Axiomatic triples to be (possibly) added to the final graph.

**Requires:** RDFLib, 4.0.0 and higher.

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**Author:** Ivan Herman

**owlrl.AxiomaticTriples.OWLRL_Axiomatic_Triples** = [(rdflib.term.URIRef('http://www.w3.org/2002/07/owl#AllDifferent'), ... rdflib.term.URIRef('http://www.w3.org/2002/07/owl#Class'))

OWL RL axiomatic triples: combination of the RDFS triples plus the OWL specific ones

**owlrl.AxiomaticTriples.OWLRL_D_Axiomatic_Triples** = [(rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#integer'), ... rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#XMLLiteral'))

OWL RL D Axiomatic triples: combination of the RDFS ones, plus some extra statements on ranges and domains, plus some OWL specific datatypes

**owlrl.AxiomaticTriples.OWLRL_Datatypes_Disjointness** = [(rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#anyURI'), ... rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#XMLLiteral'))

...
owlrl.AxiomaticTriples.OWL_D_Axiomatic_Triples_subclasses = [(rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#string'), ... rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#PlainLiteral'))

owlrl.AxiomaticTriples.RDFS_Axiomatic_Triples = [(rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#type'), ... rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#Property'))

RDFS Axiomatic Triples all together

owlrl.AxiomaticTriples.RDFS_D_Axiomatic_Triples_subclasses = [(rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#decimal'), ... rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#dateTime'))

RDFS D-entailment triples, ie, possible subclassing of various datatypes

owlrl.AxiomaticTriples.RDFS_D_Axiomatic_Triples_types = [(rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#integer'), ... rdflib.term.URIRef('http://www.w3.org/2000/01/rdf-schema#Datatype'))

See also:

View the source code AxiomaticTriples.

1.6 Closure

The generic superclasses for various rule based semantics and the possible extensions.

Requires: RDFLib, 4.0.0 and higher.

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Organization: World Wide Web Consortium

Author: Ivan Herman

class owlrl.Closure.Core (graph, axioms, daxioms, rdfs=False)
    Bases: object

Core of the semantics management, dealing with the RDFS and other Semantic triples. The only reason to have it in a separate class is for an easier maintainability.

This is a common superclass only. In the present module, it is subclassed by a RDFSClosure. RDFS_Semantics class and a OWLRL.OWLRL_Semantics class. There are some methods that are implemented in the subclasses only, ie, this class cannot be used by itself!

Parameters

• graph (rdflib.Graph) – The RDF graph to be extended.
• axioms (bool) – Whether axioms should be added or not.
• daxioms (bool) – Whether datatype axioms should be added or not.
• rdfs (bool) – Whether RDFS inference is also done (used in subclassed only).

Variables

• IMaxNum – Maximal index of rdf:_i occurrence in the graph.
• graph – The real graph.
• axioms – Whether axioms should be added or not.
• daxioms – Whether datatype axioms should be added or not.
• added_triples – Triples added to the graph, conceptually, during one processing cycle.
• error_messages – Error messages (typically inconsistency messages in OWL RL) found during processing. These are added to the final graph at the very end as separate BNodes with error messages.
• rdfs – Whether RDFS inference is also done (used in subclassed only).
add_axioms()
Add axioms.
This is only a placeholder and raises an exception by default; subclasses must fill this with real content

add_d_axioms()
Add d axioms.
This is only a placeholder and raises an exception by default; subclasses must fill this with real content

add_error(message)
Add an error message.
Parameters message (str) – Error message.

closure()
Generate the closure the graph. This is the real ‘core’.
The processing rules store new triples via the separate method Core.store_triple() which stores them in the added_triples array. If that array is empty at the end of a cycle, it means that the whole process can be stopped.
If required, the relevant axiomatic triples are added to the graph before processing in cycles. Similarly the exchange of literals against bnodes is also done in this step (and restored after all cycles are over).

empty_stored_triples()
Empty the internal store for triples.

flush_stored_triples()
Send the stored triples to the graph, and empty the container.

one_time_rules()
This is only a placeholder; subclasses should fill this with real content. By default, it is just an empty call. This set of rules is invoked only once and not in a cycle.

post_process()
Do some post-processing step. This method when all processing is done, but before handling possible errors (ie, the method can add its own error messages). By default, this method is empty, subclasses can add content to it by overriding it.

pre_process()
Do some pre-processing step. This method before anything else in the closure. By default, this method is empty, subclasses can add content to it by overriding it.

rules(t, cycle_num)
The core processing cycles through every tuple in the graph and dispatches it to the various methods implementing a specific group of rules. By default, this method raises an exception; indeed, subclasses must add content to it by overriding it.
Parameters
- t (tuple) – One triple on which to apply the rules.
- cycle_num (int) – Which cycle are we in, starting with 1. This value is forwarded to all local rules; it is also used locally to collect the bnodes in the graph.

store_triple(t)
In contrast to its name, this does not yet add anything to the graph itself, it just stores the tuple in an internal set (Core.added_triples). (It is important for this to be a set: some of the rules in the various closures may generate the same tuples several times.) Before adding the tuple to the set, the method checks whether the tuple is in the final graph already (if yes, it is not added to the set).
The set itself is emptied at the start of every processing cycle; the triples are then effectively added to the graph at the end of such a cycle. If the set is actually empty at that point, this means that the cycle has not added any new triple, and the full processing can stop.

**Parameters**

$t$ (tuple $(s,p,o)$) – The triple to be added to the graph, unless it is already there.

### 1.7 CombinedClosure

The combined closure: performing both the OWL 2 RL and RDFS closures.

The two are very close but there are some rules in RDFS that are not in OWL 2 RL (e.g., the axiomatic triples concerning the container membership properties). Using this closure class the OWL 2 RL implementation becomes a full extension of RDFS.

**Requires**: RDFLib, 4.0.0 and higher.

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**Author**: Ivan Herman

```python
class owlrl.CombinedClosure.RDFS_OWLRL_Semantics(graph, axioms, daxioms, rdfs=True)
Bases: owlrl.RDFSClosure.RDFS_Semantics, owlrl.OWLRL.OWLRL_Semantics
```

Common subclass of the RDFS and OWL 2 RL semantic classes. All methods simply call back to the functions in the superclasses. This may lead to some unnecessary duplication of terms and rules, but it is not so bad. Also, the additional identification defined for OWL Full, i.e., Resource being the same as Thing and OWL and RDFS classes being identical are added to the triple store.

Note that this class is also a possible user extension point: subclasses can be created that extend the standard functionality by extending this class. This class always performs RDFS inferences. Subclasses have to set the `self.rdfs` flag explicitly to the requested value if that is to be controlled.

**Parameters**

- `graph` (rdflib.Graph) – The RDF graph to be extended.
- `axioms` (bool) – Whether (non-datatype) axiomatic triples should be added or not.
- `daxioms` (bool) – Whether datatype axiomatic triples should be added or not.
- `rdfs` (bool) – Placeholder flag (used in subclassed only, it is always defaulted to True in this class)

**Variables**

- `full_binding_triples` – Additional axiom type triples that are added to the combined semantics; these ‘bind’ the RDFS and the OWL worlds together.
- `rdfs` (bool) Whether RDFS inference is to be performed or not. In this class instance the value is always True, subclasses may explicitly change it at initialization time.

```python
add_axioms()  # Add axioms
add_d_axioms()  # This is not really complete, because it just uses the comparison possibilities that RDFLib provides.
add_error(message)  # Add an error message
```
Parameters message *(str)* – Error message.

```java
static add_new_datatype *(uri, conversion_function, datatype_list, subsumption_dict=None, subsumption_key=None, subsumption_list=None)*
```

If an extension wants to add new datatypes, this method should be invoked at initialization time.

Parameters

- **uri** – URI for the new datatypes, like owl_ns["Rational"].
- **conversion_function** – A function converting the lexical representation of the datatype to a Python value, possibly raising an exception in case of unsuitable lexical form.
- **datatype_list** *(list)* – List of datatypes already in use that has to be checked.
- **subsumption_dict** *(dict)* – Dictionary of subsumption hierarchies (indexed by the datatype URI-s).
- **subsumption_key** *(str)* – Key in the dictionary, if None, the uri parameter is used.
- **subsumption_list** *(list)* – List of subsumptions associated to a subsumption key (ie, all datatypes that are superclasses of the new datatype).

```python
closure()
``` Generate the closure the graph. This is the real ‘core’.

The processing rules store new triples via the separate method `Core.store_triple()` which stores them in the `added_triples` array. If that array is empty at the end of a cycle, it means that the whole process can be stopped.

If required, the relevant axiomatic triples are added to the graph before processing in cycles. Similarly the exchange of literals against bnodes is also done in this step (and restored after all cycles are over).

```python
empty_stored_triples()
``` Empty the internal store for triples.

```python
flush_stored_triples()
``` Send the stored triples to the graph, and empty the container.

```python
full_binding_triples = [(rdflib.term.URIRef('http://www.w3.org/2002/07/owl#Thing'), ... rdflib.term.URIRef('http://www.w3.org/2000/01/rdf-schema#Datatype'))
```

```python
one_time_rules()
``` Adds some extra axioms and calls for the d_axiom part of the OWL Semantics.

```python
post_process()
``` Do some post-processing step. This method when all processing is done, but before handling possible errors (I.e., the method can add its own error messages). By default, this method is empty, subclasses can add content to it by overriding it.

```python
pre_process()
``` Do some pre-processing step. This method before anything else in the closure. By default, this method is empty, subclasses can add content to it by overriding it.

```python
restriction_typing_check *(v, t)*
``` Helping method to check whether a type statement is in line with a possible restriction. This method is invoked by rule “cls-avf” before setting a type on an allValuesFrom restriction.

The method is a placeholder at this level. It is typically implemented by subclasses for extra checks, e.g., for datatype facet checks.

Parameters

- **v** – The resource that is to be ‘typed’.
• **t** – The targeted type (ie, Class).

  **Returns**  Boolean.

  **Return type**  bool

  **rules** (*t*, *cycle_num*)

  **Parameters**

  • **t**  (*tuple*) – A triple (in the form of a tuple).

  • **cycle_num**  (*int*) – Which cycle are we in, starting with 1. This value is forwarded to all local rules; it is also used locally to collect the bnodes in the graph.

  **store_triple** (*t*)

  In contrast to its name, this does not yet add anything to the graph itself, it just stores the tuple in an internal set (*Core.added_triples*). (It is important for this to be a set: some of the rules in the various closures may generate the same tuples several times.) Before adding the tuple to the set, the method checks whether the tuple is in the final graph already (if yes, it is not added to the set).

  The set itself is emptied at the start of every processing cycle; the triples are then effectively added to the graph at the end of such a cycle. If the set is actually empty at that point, this means that the cycle has not added any new triple, and the full processing can stop.

  **Parameters**

  • **t**  (*tuple* (*s*, *p*, *o*)) – The triple to be added to the graph, unless it is already there

### 1.8 DatatypeHandling

Most of the XSD datatypes are handled directly by RDFLib. However, in some cases, that is not good enough. There are two major reasons for this:

1. Some datatypes are missing from RDFLib and required by OWL 2 RL and/or RDFS.

2. In other cases, though the datatype is present, RDFLib is fairly lax in checking the lexical value of those datatypes. Typical case is boolean.

Some of these deficiencies are handled by this module. All the functions convert the lexical value into a python datatype (or return the original string if this is not possible) which will be used, e.g., for comparisons (equalities). If the lexical value constraints are not met, exceptions are raised.

**Requires**: RDFLib, 4.0.0 and higher.

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**Organization**: World Wide Web Consortium

**Author**: Ivan Herman

```python
owlrl.DatatypeHandling.AltXSDToPYTHON = {rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#HTML'): <function <lambda>>, ...
```

Replacement of RDFLib’s conversion function. Each entry assigns a function to an XSD datatype, attempting to convert a string to a Python datatype (or raise an exception if some problem is found).

```python
owlrl.DatatypeHandling.use_Alt_lexical_conversions()
```

Registering the datatypes item for RDFLib, ie, bind the dictionary values. The ‘bind’ method of RDFLib adds extra datatypes to the registered ones in RDFLib, though the table used here (i.e., `AltXSDToPYTHON`) actually overrides all of the default conversion routines. The method also add a Decimal entry to the `PythonToXSD` list of RDFLib.

```python
owlrl.DatatypeHandling.use_RDFLib_lexical_conversions()
```

Restore the original (ie, RDFLib) set of lexical conversion routines.
### 1.8.1 AltXSDToPYTHON Table

**Note:** The code below is not extracted automatically from the source code.

If there are any errors, please make a pull request or an issue: https://github.com/RDFLib/OWL-RL

```python
AltXSDToPYTHON = {
    ns_xsd["language"]: lambda v: _strToVal_Regexp(v, _re_language),
    ns_xsd["NMTOKEN"]: lambda v: _strToVal_Regexp(v, _re_NMTOKEN, re.U),
    ns_xsd["Name"]: lambda v: _strToVal_Regexp(v, _re_NMTOKEN, re.U, _re_Name_ex),
    ns_xsd["NCName"]: lambda v: _strToVal_Regexp(v, _re_NCName, re.U, _re_NCName_ex),
    ns_xsd["token"]: _strToToken,
    ns_rdf["PlainLiteral"]: _strToPlainLiteral,
    ns_xsd["boolean"]: _strToBool,
    ns_xsd["decimal"]: _strToDecimal,
    ns_xsd["anyURI"]: _strToAnyURI,
    ns_xsd["base64Binary"]: _strToBase64Binary,
    ns_xsd["double"]: _strToDouble,
    ns_xsd["float"]: _strToFloat,
    ns_xsd["byte"]: lambda v: _strToBoundNumeral(v, _limits_byte, int),
    ns_xsd["int"]: lambda v: _strToBoundNumeral(v, _limits_int, int),
    ns_xsd["long"]: lambda v: _strToBoundNumeral(v, _limits_long, int),
    ns_xsd["positiveInteger"]: lambda v: _strToBoundNumeral(v, _limits_positiveInteger, int),
    ns_xsd["nonPositiveInteger"]: lambda v: _strToBoundNumeral(v, _limits_nonPositiveInteger, int),
    ns_xsd["negativeInteger"]: lambda v: _strToBoundNumeral(v, _limits_negativeInteger, int),
    ns_xsd["nonNegativeInteger"]: lambda v: _strToBoundNumeral(v, _limits_nonNegativeInteger, int),
    ns_xsd["short"]: lambda v: _strToBoundNumeral(v, _limits_short, int),
    ns_xsd["unsignedByte"]: lambda v: _strToBoundNumeral(v, _limits_unsignedByte, int),
    ns_xsd["unsignedShort"]: lambda v: _strToBoundNumeral(v, _limits_unsignedShort, int),
    ns_xsd["unsignedInt"]: lambda v: _strToBoundNumeral(v, _limits_unsignedInt, int),
    ns_xsd["unsignedLong"]: lambda v: _strToBoundNumeral(v, _limits_unsignedLong, int),
    ns_xsd["hexBinary"]: _strToHexBinary,
    ns_xsd["dateTime"]: lambda v: _strToDateTimeAndStamp(v, False),
    ns_xsd["dateTimeStamp"]: lambda v: _strToDateTimeAndStamp(v, True),
    ns_rdf["XMLLiteral"]: _strToXMLLiteral,
    ns_rdf["integer"]: int,
    ns_xsd["string"]: lambda v: v,
    ns_rdf["HTML"]: lambda v: v,
    ns_xsd["normalizedString"]: lambda v: _strToVal_Regexp(v, _re_token),

    # These are RDFS specific...
    ns_xsd["time"]: _strToTime,
    ns_xsd["date"]: _strToDate,
    ns_xsd["gYearMonth"]: _strTogYearMonth,
    ns_xsd["gYear"]: _strTogYear,
    ns_xsd["gMonthDay"]: _strTogMonthDay,
    ns_xsd["gDay"]: _strTogDay,
    ns_xsd["gMonth"]: _strTogMonth,
}
```
See also:

View the source code DatatypeHandling.

1.9 Literals

1.10 OWL

This module is a brute force implementation of the ‘finite’ version of RDFS semantics and of OWL 2 RL on the top of RDFLib (with some caveats, see below). Some extensions to these are also implemented.

Brute force means that, in all cases, simple forward chaining rules are used to extend (recursively) the incoming graph with all triples that the rule sets permit (i.e., the “deductive closure” of the graph is computed). There is an extra option whether the axiomatic triples are added to the graph (prior to the forward chaining step). These, typically set the domain and range for properties or define some core classes. In the case of RDFS, the implementation uses a ‘finite’ version of the axiomatic triples only (as proposed, for example, by Herman ter Horst). This means that it adds only those \texttt{rdf:}_i type predicates that do appear in the original graph, thereby keeping this step finite. For OWL 2 RL, OWL 2 does not define axiomatic triples formally; but they can be deduced from the OWL 2 RDF Based Semantics document and are listed in Appendix 6 (though informally).

\textbf{Note:} This implementation adds only those triples that refer to OWL terms that are meaningful for the OWL 2 RL case.

1.10.1 Package Entry Points

The main entry point to the package is via the \texttt{DeductiveClosure} class. This class should be initialized to control the parameters of the deductive closure; the forward chaining is done via the \texttt{DeductiveClosure.expand} method. The simplest way to use the package from an RDFLib application is as follows:

\begin{Verbatim}
graph = Graph()
...  # creation of an RDFLib graph
...  # normal RDFLib application, e.g.,
\rightarrow parsing RDF data
...  # without axiomatic triples
DeductiveClosure(OWLRL_Semantics).expand(graph)  # calculate an OWL 2 RL deductive closure of graph
\end{Verbatim}

The first argument of the \texttt{DeductiveClosure} initialization can be replaced by other classes, providing different types of deductive closure; other arguments are also possible. For example:

\begin{Verbatim}
DeductiveClosure(OWLRL_Extension, rdfs_closure = True, axiomatic_triples = True, datatype_axioms = True).expand(graph)
\end{Verbatim}

This will calculate the deductive closure including RDFS and some extensions to OWL 2 RL, and with all possible axiomatic triples added to the graph (this is about the maximum the package can do...)

The same instance of \texttt{DeductiveClosure} can be used for several graph expansions. In other words, the expand function does not change any state.

For convenience, a second entry point to the package is provided in the form of a function called \texttt{convert_graph()}, that expects a directory with various options, including a file name. The function parses
the file, creates the expanded graph, and serializes the result into RDF/XML or Turtle. This function is particularly
useful as an entry point for a CGI call (where the HTML form parameters are in a directory) and is easy to use with a
command line interface. The package distribution contains an example for both.

There are major closure type (ie, semantic closure possibilities); these can be controlled through the appropriate
parameters of the DeductiveClosure class:

- using the RDFS_Semantics class, implementing the RDFS semantics.
- using the OWLRL.OWLRL_Semantics class, implementing the OWL 2 RL.
- using CombinedClosure.RDFS/owlrl.Semantics class, implementing a combined se-
  mantics of RDFS semantics and OWL 2 RL.

In all three cases there are other dimensions that can control the exact closure being generated:

- for convenience, the so called axiomatic triples (see, eg, the axiomatic triples in RDFS are, by
default, I{not} added to the graph closure to reduce the number of generated triples. These can be
controlled through a separate initialization argument.
- similarly, the axiomatic triples for D-entailment are separated.

1.10.2 Some Technical/implementation aspects

The core processing is done in the in the Closure.Core class, which is subclassed by the RDFSClosure.
RDFS_Semantics and the OWLRL.OWLRL_Semantics classes (these two are then, on their turn, subclassed
by the CombinedClosure.RDFS/owlrl.Semantics class). The core implements the core functionality of
cycling through the rules, whereas the rules themselves are defined and implemented in the subclasses. There are
also methods that are executed only once either at the beginning or at the end of the full processing cycle. Adding
axiomatic triples is handled separately, which allows a finer user control over these features.

Literals must be handled separately. Indeed, the functionality relies on ‘extended’ RDF graphs, that allows literals
to be in a subject position, too. Because RDFLib does not allow that, processing begins by exchanging all literals
in the graph for bnodes (identical literals get the same associated bnode). Processing occurs on these bnodes; at
the end of the process all these bnodes are replaced by their corresponding literals if possible (if the bnode occurs in
a subject position, that triple is removed from the resulting graph). Details of this processing is handled in the separate
Literals.LiteralProxies class.

The OWL specification includes references to datatypes that are not in the core RDFS specification, consequently not
directly implemented by RDFLib. These are added in a separate module of the package.

Problems with Literals with datatypes

The current distribution of RDFLib is fairly poor in handling datatypes, particularly in checking whether a lexical form
of a literal is “proper” as for its declared datatype. A typical example is:

```
"-1234"^^xsd:nonNegativeInteger
```

which should not be accepted as valid literal. Because the requirements of OWL 2 RL are much stricter in this respect,
an alternative set of datatype handling (essentially, conversions) had to be implemented (see the XsdDatatypes
module).

The DeductiveClosure class has an additional instance variable whether the default RDFLib conversion routines
should be exchanged against the new ones. If this flag is set to True and instance creation (this is the default), then the
conversion routines are set back to the originals once the expansion is complete, thereby avoiding to influence older
application that may not work properly with the new set of conversion routines.
If the user wants to use these alternative lexical conversions everywhere in the application, then the `DeductiveClosure.use_improved_datatypes_conversions()` method can be invoked. That method changes the conversion routines and, from that point on, all usage of `DeductiveClosure` instances will use the improved conversion methods without resetting them. I.e., the code structure can be something like:

```python
DeductiveClosure().use_improved_datatypes_conversions()
... RDFLib application
DeductiveClosure().expand(graph)
...
```

The default situation can be set back using the `DeductiveClosure.use_rdflib_datatypes_conversions()` call.

It is, however, not required to use these methods at all. I.e., the user can use:

```python
DeductiveClosure(improved_datatypes=False).expand(graph)
```

which will result in a proper graph expansion except for the datatype specific comparisons which will be incomplete.

Requires:

- RDFLib, 4.0.0 and higher.
- rdflib_jsonld

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Organization: World Wide Web Consortium

Author: Ivan Herman

```python
class owlrl.DeductiveClosure(closure_class, improved_datatypes=True, rdfs_closure=False, axiomatic_triples=False, datatype_axioms=False)
```

Entry point to generate the deductive closure of a graph. The exact choice deductive closure is controlled by a class reference. The important initialization parameter is the `closure_class`, a Class object referring to a subclass of `Closure.Core`. Although this package includes a number of such subclasses `OWLRL_Semantics`, `RDFS_Semantics`, `RDFS/owlrl_Semantics`, and `OWLRL_Extension`, the user can use his/her own if additional rules are implemented.

Note that `owl:imports` statements are not interpreted in this class, that has to be done beforehand on the graph that is to be expanded.

Parameters

- `closure_class` (subclass of `Closure.Core`) – A closure class reference.
- `improved_datatypes` (bool) – Whether the improved set of lexical-to-Python conversions should be used for datatype handling. See the introduction for more details. Default: True.
- `rdfs_closure` (bool) – Whether the RDFS closure should also be executed. Default: False.
- `axiomatic_triples` (bool) – Whether relevant axiomatic triples are added before chaining, except for datatype axiomatic triples. Default: False.
- `datatype_axioms` (bool) – Whether further datatype axiomatic triples are added to the output. Default: false.

Variables `improved_datatype_generic` – Whether the improved set of lexical-to-Python conversions should be used for datatype handling in general, i.e., not only for a particular instance and not only for inference purposes. Default: False.
expand(graph)
Expand the graph using forward chaining, and with the relevant closure type.

Parameters
- **graph** *(rdflib.Graph)* – The RDF graph.

**improved_datatype_generic** = False

**static use_improved_datatypes_conversions()**
Switch the system to use the improved datatype conversion routines.

**static use_rdflib_datatypes_conversions()**
Switch the system to use the generic (RDFLib) datatype conversion routines.

cwlrl.convert_graph(options, closureClass=None)
Entry point for external scripts (CGI or command line) to parse an RDF file(s), possibly execute OWL and/or RDFS closures, and serialize back the result in some format.

Note that this entry point can be used requiring no entailment at all; because both the input and the output format for the package can be RDF/XML or Turtle, such usage would simply mean a format conversion.

If OWL 2 RL processing is required, that also means that the `owl:imports` statements are interpreted. I.e., ontologies can be spread over several files. Note, however, that the output of the process would then include all imported ontologies, too.

**Parameters**
- **options (object)** – Object with specific attributes.
- **options.sources (list)** – List of uris or file names for the source data; for each one if the name ends with ‘.ttl’, it is considered to be turtle, RDF/XML otherwise (this can be overwritten by the options.iformat, though)
- **options.text (str)** – Direct Turtle encoding of a graph as a text string (useful, eg, for a CGI call using a text field).
- **options.owlClosure (bool)** – Can be yes or no.
- **options.rdfsClosure (bool)** – Can be yes or no.
- **options.owlExtras (bool)** – Can be yes or no; whether the extra rules beyond OWL 2 RL are used or not.
- **options.axioms (bool)** – Whether relevant axiomatic triples are added before chaining (can be a boolean, or the strings “yes” or “no”).
- **options.daxioms (bool)** – Further datatype axiomatic triples are added to the output (can be a boolean, or the strings “yes” or “no”).
- **options.format (str)** – Output format, can be “turtle” or “rdfxml”.
- **options.iformat (str)** – Input format, can be “turtle”, “rdfa”, “json”, “rdfxml”, or “auto”. “auto” means that the suffix of the file is considered: “.ttl”, “.html”, “json” or “.jsonld” respectively with ‘xml’ as a fallback.
- **options.trimming (bool)** – Whether the extension to OWLRL should also include trimming.
- **closureClass** (TODO(Edmond.Chuc@csiro.au): What class is this supposed to be?) – Explicit class reference. If set, this overrides the various different other options to be used as an extension.

cwlrl.interpret_owl_imports(iformat, graph)
Interpret the owl import statements. Essentially, recursively merge with all the objects in the owl import statement, and remove the corresponding triples from the graph.
This method can be used by an application prior to expansion. It is not done by the DeductiveClosure class.

**Parameters**

- `iformat` – Input format; can be one of AUTO, TURTLE, or RDFXML. AUTO means that the suffix of the file name or URI will decide: `.ttl` means Turtle, RDF/XML otherwise. :type iformat: str

**Parameters**

- `graph` (RDFLib.Graph) – The RDFLib Graph instance to parse into.

`owlrl.return_closure_class` (owl_closure, rdfs_closure, owl_extras, trimming=False)

Return the right semantic extension class based on three possible choices (this method is here to help potential users, the result can be fed into a DeductiveClosure instance at initialization).

**Parameters**

- `owl_closure` (bool) – Whether OWL 2 RL deductive closure should be calculated.
- `rdfs_closure` (bool) – Whether RDFS deductive closure should be calculated. In case owl_closure=True, this parameter should also be used in the initialization of DeductiveClosure.
- `owl_extras` (bool) – Whether the extra possibilities (rational datatype, etc) should be added to an OWL 2 RL deductive closure. This parameter has no effect in case owl_closure=False.
- `trimming` (bool) – Whether extra trimming is done on the OWL RL + Extension output.

**Returns**

Deductive class reference or None.

**Return type**

DeductiveClosure or None

### 1.10.3 Source code

```python

""
"""

owl and OWL2 terms. Note that the set of terms is *complete*, i.e., it includes *all* OWL 2 terms, regardless of whether the term is used in OWL 2 RL or not.

**Requires**: `RDFLib`_, 4.0.0 and higher.

.. _RDFLib: https://github.com/RDFLib/rdflib

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.. _W3C Software License: http://www.w3.org/Consortium/Legal/2002/copyright-software-20021231

**Organization**: `World Wide Web Consortium`_

.. _World Wide Web Consortium: http://www.w3.org

**Author**: `Ivan Herman`_

.. _Ivan Herman: http://www.w3.org/People/Ivan/

"""

import rdflib
from rdflib import Namespace

(continues on next page)
# The OWL namespace as used for RDFLib

```python
OWLNS = Namespace("http://www.w3.org/2002/07/owl#")
annotatedSource = OWLNS["annotatedSource"]
annotatedTarget = OWLNS["annotatedTarget"]
annotatedProperty = OWLNS["annotatedProperty"]
allValuesFrom = OWLNS["allValuesFrom"]
assertionProperty = OWLNS["assertionProperty"]
backwardCompatibleWith = OWLNS["backwardCompatibleWith"]
cardinality = OWLNS["cardinality"]
complementOf = OWLNS["complementOf"]
BottomDataProperty = OWLNS["BottomDataProperty"]
BottomObjectProperty = OWLNS["BottomObjectProperty"]
datatypeComplementOf = OWLNS["datatypeComplementOf"]
deprecated = OWLNS["deprecated"]
differentFrom = OWLNS["differentFrom"]
disjointUnionOf = OWLNS["disjointUnionOf"]
disjointClasses = OWLNS["disjointClasses"]
disjointWith = OWLNS["disjointWith"]
distinctMembers = OWLNS["distinctMembers"]
equivalentClass = OWLNS["equivalentClass"]
equivalentProperty = OWLNS["equivalentProperty"]
hasKey = OWLNS["hasKey"]
hasValue = OWLNS["hasValue"]
hasSelf = OWLNS["hasSelf"]
imports = OWLNS["imports"]
incompatibleWith = OWLNS["incompatibleWith"]
intersectionOf = OWLNS["intersectionOf"]
inverseOf = OWLNS["inverseOf"]
maxCardinality = OWLNS["maxCardinality"]
maxQualifiedCardinality = OWLNS["maxQualifiedCardinality"]
members = OWLNS["members"]
minCardinality = OWLNS["minCardinality"]
minQualifiedCardinality = OWLNS["minQualifiedCardinality"]
onClass = OWLNS["onClass"]
onDataRange = OWLNS["onDataRange"]
onDatatype = OWLNS["onDatatype"]
oneOf = OWLNS["oneOf"]
onProperty = OWLNS["onProperty"]
onProperties = OWLNS["onProperties"]
OWLpredicate = OWLNS["predicate"]
priorVersion = OWLNS["priorVersion"]
propertyChainAxiom = OWLNS["propertyChainAxiom"]
propertyDisjointWith = OWLNS["propertyDisjointWith"]
qualifiedCardinality = OWLNS["qualifiedCardinality"]
sameAs = OWLNS["sameAs"]
someValuesFrom = OWLNS["someValuesFrom"]
sourceIndividual = OWLNS["sourceIndividual"]
OWLsubject = OWLNS["subject"]
targetIndividual = OWLNS["targetIndividual"]
targetValue = OWLNS["targetValue"]
TopDataProperty = OWLNS["TopDataProperty"]
TopObjectProperty = OWLNS["TopObjectProperty"]
unionOf = OWLNS["unionOf"]
versionInfo = OWLNS["versionInfo"]
```

1.11 OWLRL

This module is a brute force implementation of the OWL 2 RL profile.

RDFLib works with 'generalized' RDF, meaning that triples with a BNode predicate are allowed. This is good because, e.g., some of the triples generated for RDF from an OWL 2 functional syntax might look like \( \text{owl:inverseOf } p \), and the RL rules would then operate on such generalized triple. However, as a last, post processing steps, these triples are removed from the graph before serialization to produce 'standard' RDF (which is o.k. for RL, too, because the consequent triples are all right, generalized triples might have had a role in the deduction steps only).

Requires: RDFLib, 4.0.0 and higher.

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Organization: World Wide Web Consortium

Author: Ivan Herman

class owlrl.OWLRL/owlrl_Semantics(graph, axioms, daxioms, rdfs=None)
Bases: owlrl.Closure.Core

OWL 2 RL Semantics class, i.e., implementation of the OWL 2 RL closure graph.

Note: Note that the module does not implement the so called Datatype entailment rules, simply because the underlying RDFLib does not implement the datatypes (i.e., RDFLib will not make the literal “1.00” and
“1.00000” identical, although even with all the ambiguities on datatypes, this should be made equal...).

Also, the so-called extensional entailment rules (Section 7.3.1 in the RDF Semantics document) have not been implemented either.

The comments and references to the various rule follow the names as used in the OWL 2 RL document.

Parameters

- **graph** (:class:`rdflib.Graph`) – The RDF graph to be extended.
- **axioms** (**bool**) – Whether (non-datatype) axiomatic triples should be added or not.
- **daxioms** (**bool**) – Whether datatype axiomatic triples should be added or not.
- **rdfs** (**bool**) – Whether RDFS inference is also done (used in subclassed only).

**add_axioms**

Add axioms

**add_d_axioms**

Add the datatype axioms

**add_error** (**message**)

Add an error message

Parameters **message** (**str**) – Error message.

**closure**

Generate the closure the graph. This is the real ‘core’.

The processing rules store new triples via the separate method :func:`Core.store_triple()` which stores them in the `added_triples` array. If that array is empty at the end of a cycle, it means that the whole process can be stopped.

If required, the relevant axiomatic triples are added to the graph before processing in cycles. Similarly the exchange of literals against bnodes is also done in this step (and restored after all cycles are over).

**empty_stored_triples**

Empty the internal store for triples.

**flush_stored_triples**

Send the stored triples to the graph, and empty the container.

**one_time_rules**

Some of the rules in the rule set are axiomatic in nature, meaning that they really have to be added only once, there is no reason to add these in a cycle. These are performed by this method that is invoked only once at the beginning of the process.

These are: cls-thing, cls-nothing1, prp-ap, dt-types1, dt-types2, dt-eq, dt-diff.

**post_process**

Remove triples with Bnode predicates. The Bnodes in the graph are collected in the first cycle run.

**pre_process**

Do some pre-processing step. This method before anything else in the closure. By default, this method is empty, subclasses can add content to it by overriding it.

**restriction_typing_check** (**v**, **t**)

Helping method to check whether a type statement is in line with a possible restriction. This method is invoked by rule “cls-avf” before setting a type on an allValuesFrom restriction.

The method is a placeholder at this level. It is typically implemented by subclasses for extra checks, e.g., for datatype facet checks.
Parameters

• v – The resource that is to be ‘typed’.
• t – The targeted type (i.e., Class).

Returns Boolean.

Return type bool

rules (t, cycle_num)
Go through the various rule groups, as defined in the OWL-RL profile text and implemented via local methods. (The calling cycle takes every tuple in the graph.)

Parameters

• t – A triple (in the form of a tuple).
• cycle_num – Which cycle are we in, starting with 1. This value is forwarded to all local rules; it is also used locally to collect the bnodes in the graph.

store_triple (t)
In contrast to its name, this does not yet add anything to the graph itself, it just stores the tuple in an internal set (Core.added_triples). (It is important for this to be a set: some of the rules in the various closures may generate the same tuples several times.) Before adding the tuple to the set, the method checks whether the tuple is in the final graph already (if yes, it is not added to the set).

The set itself is emptied at the start of every processing cycle; the triples are then effectively added to the graph at the end of such a cycle. If the set is actually empty at that point, this means that the cycle has not added any new triple, and the full processing can stop.

Parameters t (tuple (s, p, o)) – The triple to be added to the graph, unless it is already there.

owlrl.OWLRL.identity (v)

1.12 OWLRLExtras

Extension to OWL 2 RL, i.e., some additional rules added to the system from OWL 2 Full. It is implemented through the OWLRL_Extension class, whose reference has to be passed to the relevant semantic class (i.e., either the OWL 2 RL or the combined closure class) as an ‘extension’.

The added rules and features are:

• self restriction
• owl:rational datatype
• datatype restrictions via facets

In more details, the rules that are added:

   rdf:type ?z.

Requires: RDFLib, 4.0.0 and higher.

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Organization: World Wide Web Consortium
Author: Ivan Herman

class owlrl.OWLRLExtras.OWLRL_Extension(graph, axioms, daxioms, rdfs=False)
    Bases: owlrl.CombinedClosure.RDFS_OWLRL_Semantics

Additional rules to OWL 2 RL. The initialization method also adds the owl:rational datatype to the set of allowed datatypes with the _strToRational() function as a conversion between the literal form and a Rational. The xsd:decimal datatype is also set to be a subclass of owl:rational. Furthermore, the restricted datatypes are extracted from the graph using a separate method in a different module (RestrictedDatatype.extract_faceted_datatypes()), and all those datatypes are also added to the set of allowed datatypes. In the case of the restricted datatypes and extra subsumption relationship is set up between the restricted and the base datatypes.

Variables

• **extra_axioms** – Additional axioms that have to be added to the deductive closure (in case the axiomatic triples are required).
• **restricted_datatypes** – list of the datatype restriction from RestrictedDatatype.

add_axioms()
    Add the OWLRL_Extension.extra_axioms, related to the self restrictions.

add_d_axioms()
    This is not really complete, because it just uses the comparison possibilities that RDFLib provides.

add_error(message)
    Add an error message

Parameters message (str) – Error message.

static add_new_datatype(uri, conversion_function, datatype_list, subsumption_dict=None, subsumption_key=None, subsumption_list=None)
    If an extension wants to add new datatypes, this method should be invoked at initialization time.

Parameters

• **uri** – URI for the new datatypes, like owl_ns[“Rational”].
• **conversion_function** – A function converting the lexical representation of the datatype to a Python value, possibly raising an exception in case of unsuitable lexical form.
• **datatype_list (list)** – List of datatypes already in use that has to be checked.
• **subsumption_dict (dict)** – Dictionary of subsumption hierarchies (indexed by the datatype URI-s).
• **subsumption_key (str)** – Key in the dictionary, if None, the uri parameter is used.
• **subsumption_list (list)** – List of subsumptions associated to a subsumption key (ie, all datatypes that are superclasses of the new datatype).

closure()
    Generate the closure the graph. This is the real ‘core’.

The processing rules store new triples via the separate method Core.store_triple() which stores them in the added_triples array. If that array is empty at the end of a cycle, it means that the whole process can be stopped.

If required, the relevant axiomatic triples are added to the graph before processing in cycles. Similarly the exchange of literals against bnodes is also done in this step (and restored after all cycles are over).
empty_stored_triples()
Empty the internal store for triples.

extra_axioms = [(rdflib.term.URIRef('http://www.w3.org/2002/07/owl#hasSelf'), rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#Property'))]

flush_stored_triples()
Send the stored triples to the graph, and empty the container.

full_binding_triples = [(rdflib.term.URIRef('http://www.w3.org/2002/07/owl#Thing'), rdflib.term.URIRef('http://www.w3.org/2000/01/rdf-schema#Datatype'))]

one_time_rules()
This method is invoked only once at the beginning, and prior of, the forward chaining process.

At present, only the L{subsumption} of restricted datatypes<subsume_restricted_datatypes>} is performed.

post_process()
Do some post-processing step. This method when all processing is done, but before handling possible errors (i.e., the method can add its own error messages). By default, this method is empty, subclasses can add content to it by overriding it.

pre_process()
Do some pre-processing step. This method before anything else in the closure. By default, this method is empty, subclasses can add content to it by overriding it.

restriction_typing_check\((v, t)\)
Helping method to check whether a type statement is in line with a possible restriction. This method is invoked by rule “cls-avf” before setting a type on an allValuesFrom restriction.

The method is a placeholder at this level. It is typically implemented by subclasses for extra checks, e.g., for datatype facet checks.

Parameters
• \(v\) – the resource that is to be ‘typed’.
• \(t\) – the targeted type (i.e., Class).

Returns Boolean.

Return type bool

rules\((t, cycle_num)\)
Go through the additional rules implemented by this module.

Parameters
• \(t\) (tuple) – A triple (in the form of a tuple).
• \(cycle_num\) (int) – Which cycle are we in, starting with 1. This value is forwarded to all local rules; it is also used locally to collect the bnodes in the graph.

store_triple\((t)\)
In contrast to its name, this does not yet add anything to the graph itself, it just stores the tuple in an internal set (Core.added_triples). (It is important for this to be a set: some of the rules in the various closures may generate the same tuples several times.) Before adding the tuple to the set, the method checks whether the tuple is in the final graph already (if yes, it is not added to the set).

The set itself is emptied at the start of every processing cycle; the triples are then effectively added to the graph at the end of such a cycle. If the set is actually empty at that point, this means that the cycle has not added any new triple, and the full processing can stop.

Parameters \(t\) (tuple \((s, p, o)\)) – The triple to be added to the graph, unless it is already there
class owrl.OWLRLExtras.OWLRL_Extension_Trimming (graph, axioms, daxioms, rdfs=False)
Bases: owrl.OWLRLExtras.OWLRL_Extension

This Class adds only one feature to OWLRL_Extension: to initialize with a trimming flag set to True by default.

This is pretty experimental and probably contentious: this class removes a number of triples from the Graph at the very end of the processing steps. These triples are either the by-products of the deductive closure calculation or are axiom like triples that are added following the rules of OWL 2 RL. While these triples are necessary for the correct inference of really ‘useful’ triples, they may not be of interest for the application for the end result.

The triples that are removed are of the form (following a SPARQL-like notation):

- For a datatype that does not appear explicitly in a type assignments (ie, in a ?x rdf:type dt) the corresponding dt rdf:type owl:Datatype and dt rdf:type owl:DataRange triples, as well as the disjointness statements with other datatypes.
- annotation property axioms.
- a number of axiomatic triples on owl:Thing, owl:Nothing and rdf:Resource (eg, owl:Nothing rdf:type owl:Class, owl:Thing owl:equivalentClass rdf:Resource, etc).

Trimming is the only feature of this class, done in the post_process() step. If users extend OWLRL_Extension, this class can be safely mixed in via multiple inheritance.

Parameters

- **graph** (rdflib.Graph) – The RDF graph to be extended.
- **axioms** (bool) – Whether (non-datatype) axiomatic triples should be added or not.
- **daxioms** (bool) – Whether datatype axiomatic triples should be added or not.
- **rdfs** (bool) – Whether RDFS extension is done.

add_axioms ()
Add the OWLRL_Extension.extra_axioms, related to the self restrictions.

add_d_axioms ()
This is not really complete, because it just uses the comparison possibilities that RDFLib provides.

add_error (message)
Add an error message

Parameters **message** (str) – Error message.

static add_new_datatype (uri, conversion_function, datatype_list, subsumption_dict=None, subsumption_key=None, subsumption_list=None)
If an extension wants to add new datatypes, this method should be invoked at initialization time.

Parameters

- **uri** – URI for the new datatypes, like owl_ns[“Rational”].
- **conversion_function** – A function converting the lexical representation of the datatype to a Python value, possibly raising an exception in case of unsuitable lexical form.
- **datatype_list** (list) – List of datatypes already in use that has to be checked.
• **subsumption_dict** *(dict)* – Dictionary of subsumption hierarchies (indexed by the datatype URI-s).

• **subsumption_key** *(str)* – Key in the dictionary, if None, the uri parameter is used.

• **subsumption_list** *(list)* – List of subsumptions associated to a subsumption key (ie, all datatypes that are superclasses of the new datatype).

closure()
Generate the closure the graph. This is the real ‘core’.

The processing rules store new triples via the separate method Core.store_triple() which stores them in the added_triples array. If that array is empty at the end of a cycle, it means that the whole process can be stopped.

If required, the relevant axiomatic triples are added to the graph before processing in cycles. Similarly the exchange of literals against bnodes is also done in this step (and restored after all cycles are over).

effective_ontologies() –

Empty the internal store for triples.

extra_axioms = [(rdflib.term.URIRef('http://www.w3.org/2002/07/owl#hasSelf'), rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#Property'))]

flush_stored_triples()
Send the stored triples to the graph, and empty the container.

full_binding_triples = [(rdflib.term.URIRef('http://www.w3.org/2002/07/owl#Thing'), rdflib.term.URIRef('http://www.w3.org/2000/01/rdf-schema#Datatype'))]

one_time_rules()
This method is invoked only once at the beginning, and prior of, the forward chaining process.

At present, only the L{subsumption} of restricted datatypes<subsumption> is performed.

post_process()
Do some post-processing step performing the trimming of the graph. See the OWLRL_Extension_Has_Self class for further details.

pre_process()
Do some pre-processing step. This method before anything else in the closure. By default, this method is empty, subclasses can add content to it by overriding it.

restriction_typing_check(v, t)
Helping method to check whether a type statement is in line with a possible restriction. This method is invoked by rule “cls-avf” before setting a type on an allValuesFrom restriction.

The method is a placeholder at this level. It is typically implemented by subclasses for extra checks, e.g., for datatype facet checks.

Parameters
• **v** – the resource that is to be ‘typed’.
• **t** – the targeted type (i.e., Class).

Returns Boolean.

Return type bool

rules(t, cycle_num)
Go through the additional rules implemented by this module.

Parameters
• **t** *(tuple)* – A triple (in the form of a tuple).
• **cycle_num** *(int)* – Which cycle are we in, starting with 1. This value is forwarded to all local rules; it is also used locally to collect the bnodes in the graph.

**store_triple** *(t)*

In contrast to its name, this does not yet add anything to the graph itself, it just stores the tuple in an internal set (`Core.added_triples`). (It is important for this to be a set: some of the rules in the various closures may generate the same tuples several times.) Before adding the tuple to the set, the method checks whether the tuple is in the final graph already (if yes, it is not added to the set).

The set itself is emptied at the start of every processing cycle; the triples are then effectively added to the graph at the end of such a cycle. If the set is actually empty at that point, this means that the cycle has not added any new triple, and the full processing can stop.

**Parameters** **t** *(tuple (s,p,o)) –* The triple to be added to the graph, unless it is already there

### 1.13 RDFS

**RDF(S) terms.** Note that the set of terms is *complete*, i.e., it includes *all* OWL 2 terms, regardless of whether the term is used in OWL 2 RL or not.

**Requires**: `RDFLib`_, 4.0.0 and higher.

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**Organization**: World Wide Web Consortium

**Author**: Ivan Herman

#### 1.13.1 Source code

```python
import rdflib
from rdflib import Namespace
```

(continues on next page)
24 RDFNS = Namespace("http://www.w3.org/1999/02/22-rdf-syntax-ns#")
25 RDFSNS = Namespace("http://www.w3.org/2000/01/rdf-schema#")
26
# RDF Classes
27 Seq = RDFNS["Seq"]
28 Bag = RDFNS["Bag"]
29 Alt = RDFNS["Alt"]
30 Statement = RDFNS["Statement"]
31 Property = RDFNS["Property"]
32 XMLLiteral = RDFNS["XMLLiteral"]
33 HTMLLiteral = RDFNS["HTML"]
34 LangString = RDFNS["LangString"]
35 List = RDFNS["List"]
36
# RDF Properties
37 rdf_subject = RDFNS["subject"]
38 rdf_predicate = RDFNS["predicate"]
39 rdf_object = RDFNS["object"]
40 rdf_type = RDFNS["type"]
41 value = RDFNS["value"]
42 first = RDFNS["first"]
43 rest = RDFNS["rest"]
44 # and _n where n is a non-negative integer
45
# RDF Resources
46 nil = RDFNS["nil"]
47
Resource = RDFSNS["Resource"]
48 Class = RDFSNS["Class"]
49 subClassOf = RDFSNS["subClassOf"]
50 subPropertyOf = RDFSNS["subPropertyOf"]
51 comment = RDFSNS["comment"]
52 label = RDFSNS["label"]
53 rdfs_domain = RDFSNS["domain"]
54 rdfs_range = RDFSNS["range"]
55 seeAlso = RDFSNS["seeAlso"]
56 isDefinedBy = RDFSNS["isDefinedBy"]
57 Literal = RDFSNS["Literal"]
58 Container = RDFSNS["Container"]
59 ContainerMembershipProperty = RDFSNS["ContainerMembershipProperty"]
60 member = RDFSNS["member"]
61 Datatype = RDFSNS["Datatype"]

1.14 RDFSClosure

This module is brute force implementation of the RDFS semantics on the top of RDFLib (with some caveats, see in the introductory text).

Requires: RDFLib, 4.0.0 and higher.

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Organization: World Wide Web Consortium

Author: Ivan Herman
class owlrl.RDFSClosure.RDFS_Semantics (graph, axioms, daxioms, rdfs)
Bases: owlrl.Closure.Core

RDFS Semantics class, ie, implementation of the RDFS closure graph.

Note: Note that the module does not implement the so called Datatype entailment rules, simply because the underlying RDFLib does not implement the datatypes (ie, RDFLib will not make the literal “1.00” and “1.00000” identical, although even with all the ambiguities on datatypes, this I{should} be made equal...). Also, the so-called extensional entailment rules (Section 7.3.1 in the RDF Semantics document) have not been implemented either.

The comments and references to the various rule follow the names as used in the RDF Semantics document.

Parameters
- graph (rdflib.Graph) – The RDF graph to be extended.
- axioms (bool) – Whether (non-datatype) axiomatic triples should be added or not.
- daxioms (bool) – Whether datatype axiomatic triples should be added or not.
- rdfs (bool) – Whether RDFS inference is also done (used in subclassed only).

add_axioms ()
Add axioms

add_d_axioms ()
This is not really complete, because it just uses the comparison possibilities that RDFLib provides.

add_error (message)
Add an error message

Parameters message (str) – Error message.

closure ()
Generate the closure the graph. This is the real ‘core’.

The processing rules store new triples via the separate method Core.store_triple() which stores them in the added_triples array. If that array is empty at the end of a cycle, it means that the whole process can be stopped.

If required, the relevant axiomatic triples are added to the graph before processing in cycles. Similarly the exchange of literals against bnodes is also done in this step (and restored after all cycles are over).

empty_stored_triples ()
Empty the internal store for triples.

flush_stored_triples ()
Send the stored triples to the graph, and empty the container.

one_time_rules ()
Some of the rules in the rule set are axiomatic in nature, meaning that they really have to be added only once, there is no reason to add these in a cycle. These are performed by this method that is invoked only once at the beginning of the process.

In this case this is related to a ‘hidden’ same as rules on literals with identical values (though different lexical values).

post_process ()
Do some post-processing step. This method when all processing is done, but before handling possible
errors (ie, the method can add its own error messages). By default, this method is empty, subclasses can add content to it by overriding it.

**pre_process()**

Do some pre-processing step. This method before anything else in the closure. By default, this method is empty, subclasses can add content to it by overriding it.

**rules (t, cycle_num)**

Go through the RDFS entailment rules rdf1, rdfs4-rdfs12, by extending the graph.

**Parameters**

- **t (tuple)** – A triple (in the form of a tuple).
- **cycle_num (int)** – Which cycle are we in, starting with 1. Can be used for some (though minor) optimization.

**store_triple (t)**

In contrast to its name, this does not yet add anything to the graph itself, it just stores the tuple in an internal set (Core.added_triples). (It is important for this to be a set: some of the rules in the various closures may generate the same tuples several times.) Before adding the tuple to the set, the method checks whether the tuple is in the final graph already (if yes, it is not added to the set).

The set itself is emptied at the start of every processing cycle; the triples are then effectively added to the graph at the end of such a cycle. If the set is actually empty at that point, this means that the cycle has not added any new triple, and the full processing can stop.

**Parameters**

- **t (tuple (s,p,o))** – The triple to be added to the graph, unless it is already there

### 1.15 RestrictedDatatype

Module to datatype restrictions, i.e., data ranges.

The module implements the following aspects of datatype restrictions:

- a new datatype is created run-time and added to the allowed and accepted datatypes; literals are checked whether they abide to the restrictions
- the new datatype is defined to be a ‘subClass’ of the restricted datatype
- literals of the restricted datatype and that abide to the restrictions defined by the facets are also assigned to be of the new type

The last item is important to handle the following structures:

```xml
ex:RE a owl:Restriction ;
   owl:onProperty ex:p ;
   owl:someValuesFrom [ a rdfs:Datatype ;
      owl:onDatatype xsd:string ;
      owl:withRestrictions ( [ xsd:minLength "3"^^xsd:integer ]
            [ xsd:maxLength "6"^^xsd:integer ] )
      ]
].

ex:q ex:p "abcd"^^xsd:string.
```
In the case above the system can then infer that `ex:q` is also of type `ex:RE`.

Datatype restrictions are used by the `OWLRLExtras.OWLRL_Extension` extension class.

The implementation is **not** 100% complete. Some things that an ideal implementation should do are not done yet like:

- checking whether a facet is of a datatype that is allowed for that facet
- handling of non-literals in the facets (ie, if the resource is defined to be of type literal, but whose value is defined via a separate `owl:sameAs` somewhere else)

**Requires**: RDFLib, 4.0.0 and higher.

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**Organization**: World Wide Web Consortium

**Author**: Ivan Herman

```python
owlrl.RestrictedDatatype.Datatypes_per_facets = {0: [rdflib.term.URIRef('http://www.w3.org/2002/07/owl#rational'), ... 3: [rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#plainLiteral')]

Dictionary of all the datatypes, keyed by category

owlrl.RestrictedDatatype.LENGTH = 1

Constant for datatypes using length, minLength, and maxLength (and nothing else)

owlrl.RestrictedDatatype.LENGTH_AND_PATTERN = 2

Constant for datatypes using length, minLength, maxLength, and pattern

owlrl.RestrictedDatatype.LENGTH_PATTERN_LRANGE = 3

Constant for datatypes using length, minLength, maxLength, pattern, and lang range

owlrl.RestrictedDatatype.MIN_MAX = 0

Constant for datatypes using min, max (inclusive and exclusive):

```class` owlrl.RestrictedDatatype.RestrictedDatatype(type_uri, base_type, facets)

Implementation of a datatype with facets, ie, datatype with restrictions.

**Parameters**

- `type_uri` – URI of the datatype being defined.
- `base_type` – URI of the base datatype, ie, the one being restricted.
- `facets` – List of `(facetURI, value)` pairs.

:iivar` datatype : The URI for this datatype.

**Variables**

- `base_type` – URI of the datatype that is restricted.
- `converter` – Method to convert a literal of the base type to a Python value (DatatypeHandling.AltXSDToPYTHON).
- `minExclusive` – Value for the `xsd:minExclusive` facet, initialized to `None` and set to the right value if a facet is around.
- `minInclusive` – Value for the `xsd:minInclusive` facet, initialized to `None` and set to the right value if a facet is around.
- `maxExclusive` – Value for the `xsd:maxExclusive` facet, initialized to `None` and set to the right value if a facet is around.
- `maxInclusive` – Value for the `xsd:maxInclusive` facet, initialized to `None` and set to the right value if a facet is around.
• **minLength** – Value for the xsd:minLength facet, initialized to `None` and set to the right value if a facet is around.

• **maxLength** – Value for the xsd:maxLength facet, initialized to `None` and set to the right value if a facet is around.

• **length** – Value for the xsd:length facet, initialized to `None` and set to the right value if a facet is around.

• **pattern** – Array of patterns for the xsd:pattern facet, initialized to `[]` and set to the right value if a facet is around.

• **langRange** – Array of language ranges for the rdf:langRange facet, initialized to `[]` and set to the right value if a facet is around.

• **check_methods** – List of class methods that are relevant for the given base_type.

• **toPython** – Function to convert a Literal of the specified type to a Python value. Is defined by `lambda v: _lit_to_value(self, v), see _lit_to_value()`.

```python
class owlrl.RestrictedDatatype

checkValue (value)
Check whether the (Python) value abides to the constraints defined by the current facets.

Parameters

value – The value to be checked.

Return type bool
```

```python
class owlrl.RestrictedDatatype.RestrictedDatatypeCore (type_uri, base_type)
Bases: object

An ‘abstract’ superclass for datatype restrictions. The instance variables listed here are used in general, without the specificities of the concrete restricted datatype.

This module defines the RestrictedDatatype class that corresponds to the datatypes and their restrictions defined in the OWL 2 standard. Other modules may subclass this class to define new datatatypes with restrictions.

Variables

• type_uri – The URI for this datatype.

• base_type – URI of the datatype that is restricted.

• toPython – Function to convert a Literal of the specified type to a Python value.

checkValue (value)
Check whether the (Python) value abides to the constraints defined by the current facets.

Parameters

value – The value to be checked.

Return type bool
```

```python
class owlrl.RestrictedDatatype.extract_faceted_datatypes (core, graph)
Extractions of restricted (i.e., faceted) datatypes from the graph.

Parameters

• core (Closure.Core) – The core closure instance that is being handled.

• graph (RDFLib.Graph) – RDFLib graph.

Returns List of RestrictedDatatype instances.

Return type list
```

```python
class owlrl.RestrictedDatatype

facetable_datatypes = [rdflib.term.URIRef('http://www.w3.org/2002/07/owl#rational'), ...
                                 rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#plainLiteral')]
```

1.15. RestrictedDatatype

---

**OWL-RL Documentation, Release 5.2.1**
owrl1.RestrictedDatatype._lit_to_value(dt, v)

This method is used to convert a string to a value with facet checking. RDF Literals are converted to Python values using this method; if there is a problem, an exception is raised (and caught higher up to generate an error message).

The method is the equivalent of all the methods in the DatatypeHandling module, and is registered to the system run time, as new restricted datatypes are discovered.

(Technically, the registration is done via a lambda v: _lit_to_value(self,v) setting from within a RestrictedDatatype instance).

Parameters

• dt (RestrictedDatatype) – Faceted datatype.
• v – Literal to be converted and checked.

Raises ValueError – Invalid literal value.

1.16 XsdDatatypes

Lists of XSD datatypes and their mutual relationships

Requires: RDFLib, 4.0.0 and higher.

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Organization: World Wide Web Consortium

Author: Ivan Herman

owrl1.XsdDatatypes.OWLDatatypeSubsumptions = {rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#NCName'): ... rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#decimal')

OWL Datatype subsumptions: at the moment, there is no extra to XSD

owrl1.XsdDatatypes.OWLRLDatatypes = [rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#integer'), ... rdflib.term.URIRef('http://www.w3.org/1999/02/22-rdf-syntax-ns#PlainLiteral')

OWL RL Datatypes: the basic ones plus plain literal

owrl1.XsdDatatypes.RDFSDatatypeSubsumptions = {rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#string'): ... rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#gMonth')

RDFS Datatype subsumptions: at the moment, there is no extra to XSD

owrl1.XsdDatatypes.RDFSDatatypes = [rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#integer'), ... rdflib.term.URIRef('http://www.w3.org/2001/XMLSchema#gMonth')

RDFS Datatypes: the basic ones plus the complete set of day/month ones

See also:

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