Semantic Web Guidelines for domain knowledge interoperability to build the Semantic Web of Things

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Semantic Web of Things (SWoT) is a new field to combine Semantic Web technologies and Internet of Things. Firstly, domain experts constantly redefined new domain knowledge (ontology and rules) without considering the existing ones. Secondly, domain experts are not aware of the semantic web best practices or semantic web tools. The OneM2M standard is relevant to spread the semantic web best practices and encourage domain experts to choose semantic web tools to develop the domain knowledge, in order to reuse easily they ontology-based works. Further, there is a need to standardize domain ontologies.

The following guidelines should be taken into account when defining new domain knowledge.

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Chapter 1. Manual tips

We recommend **good practices**

You can encounter some errors using tools.

You can encounter some difficulties

Chapter 2. Semantic web guidelines

I. Design your ontology

Good tutorials:

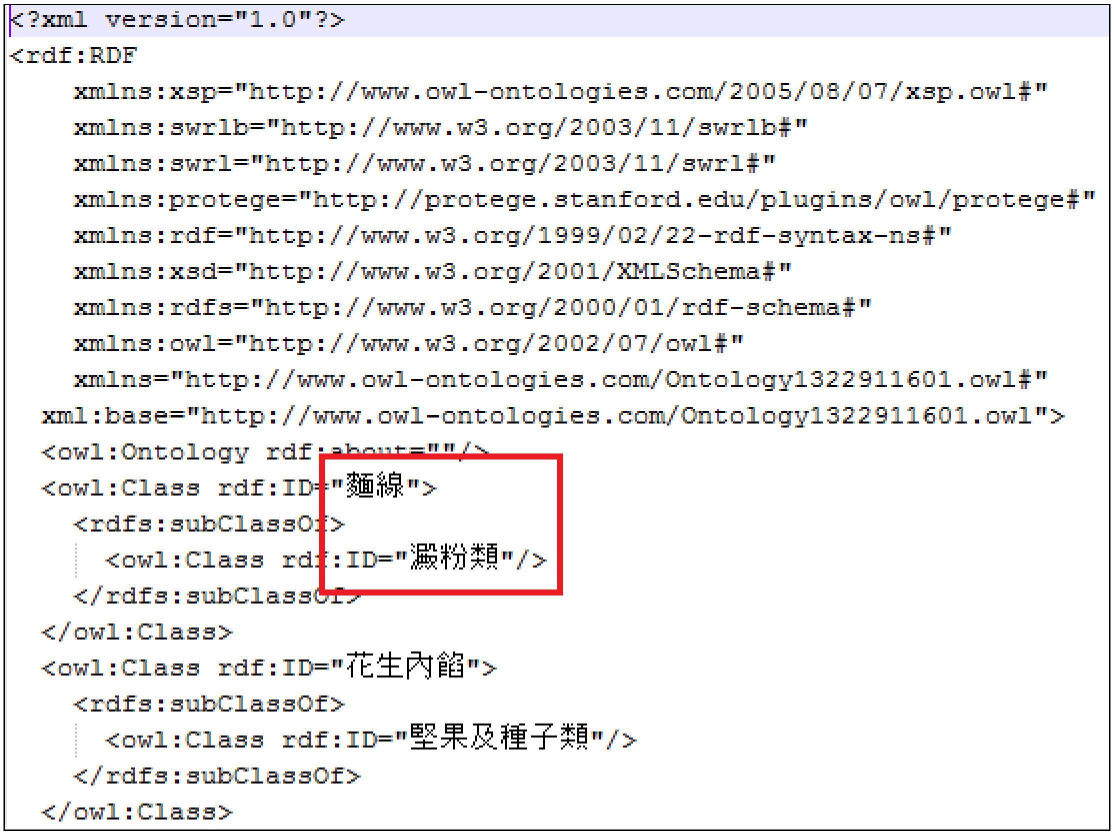
- Paper: Ontology Development 101: A Guide to Creating Your First Ontology [Noy and McGuiness. 2001]
- OWL Pizzas: Practical Experience of Teaching OWL-DL: Common Errors and Common Patterns

More difficult to read:

- Best Practice Recipes for Publishing RDF Vocabularies

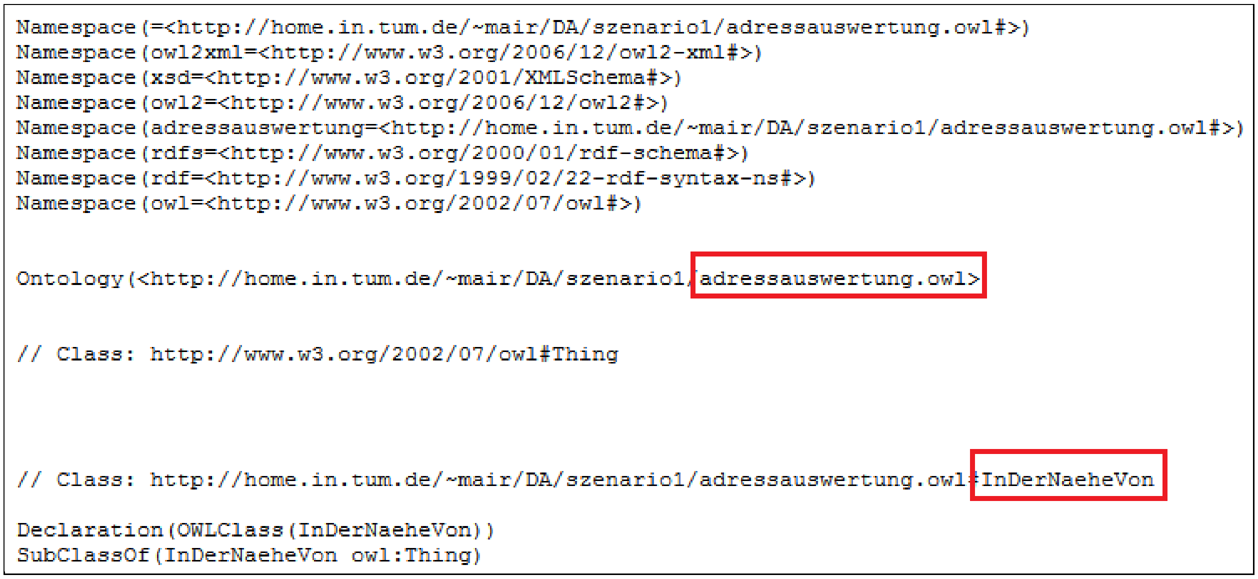
II. Domain knowledge at least written in English

Describe your domain knowledge at least in **English**. You can describe labels and comments in various languages if needed. In the Figure 1 and Figure 2, as you can see, if you are not familiar with the Chinese or German language you cannot reuse these works. These ontologies come from an ontology-based diet recommendation system [11] and intelligent transportation system project [12].



```
<?xml version="1.0"?>
<rdf:RDF
    xmlns:xsp="http://www.owl-ontologies.com/2005/08/07/xsp.owl#"
    xmlns:swrlb="http://www.w3.org/2003/11/swrlb#"
    xmlns:swrl="http://www.w3.org/2003/11/swrl#"
    xmlns:protege="http://protege.stanford.edu/plugins/owl/protege#"
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:owl="http://www.w3.org/2002/07/owl#"
    xmlns="http://www.owl-ontologies.com/Ontology1322911601.owl#"
  xml:base="http://www.owl-ontologies.com/Ontology1322911601.owl">
  <owl:Ontology rdf:about=""/>
  <owl:Class rdf:ID="麵線">
    <rdfs:subClassOf>
      <owl:Class rdf:ID="澱粉類"/>
    </rdfs:subClassOf>
  </owl:Class>
  <owl:Class rdf:ID="花生內餡">
    <rdfs:subClassOf>
      <owl:Class rdf:ID="堅果及種子類"/>
    </rdfs:subClassOf>
  </owl:Class>
```

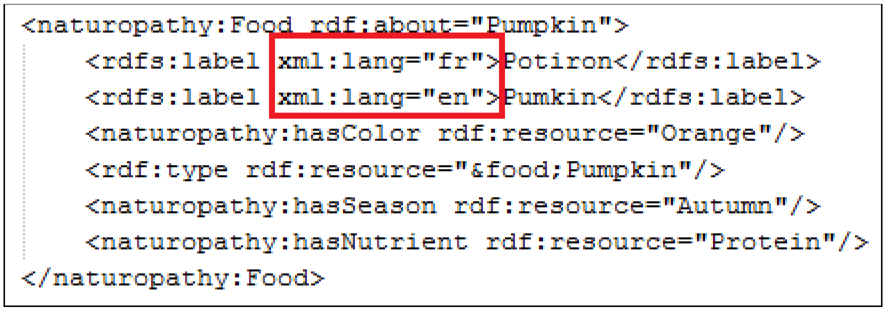
Figure 1. Ontology [11] only written in Chinese is not easily reusable



```
Namespace(=<http://home.in.tum.de/~mair/DA/szenario1/adressauswertung.owl#>)
Namespace(owl2xml=<http://www.w3.org/2006/12/owl2-xml#>)
Namespace(xsd=<http://www.w3.org/2001/XMLSchema#>)
Namespace(owl2=<http://www.w3.org/2006/12/owl2#>)
Namespace(adressauswertung=<http://home.in.tum.de/~mair/DA/szenario1/adressauswertung.owl#>)
Namespace(rdfs=<http://www.w3.org/2000/01/rdf-schema#>)
Namespace(rdf=<http://www.w3.org/1999/02/22-rdf-syntax-ns#>)
Namespace(owl=<http://www.w3.org/2002/07/owl#>)


Ontology(<http://home.in.tum.de/~mair/DA/szenario1/adressauswertung.owl>


// Class: http://www.w3.org/2002/07/owl#Thing



// Class: http://home.in.tum.de/~mair/DA/szenario1/adressauswertung.owl#InDerNaeheVon

Declaration(OWLClass(InDerNaeheVon))
SubClassOf(InDerNaeheVon owl:Thing)
```

Figure 2. Ontology [12] only written in German is not easily reusable

The **good practice** is to describe your ontology at least in English and if needed in another language as depicted in Figure 3, extracted from the naturopathy dataset.



```
<naturopathy:Food rdf:about="Pumpkin">
    <rdfs:label xml:lang="fr">Potiron</rdfs:label>
    <rdfs:label xml:lang="en">Pumkin</rdfs:label>
    <naturopathy:hasColor rdf:resource="Orange"/>
    <rdf:type rdf:resource="&food;Pumpkin"/>
    <naturopathy:hasSeason rdf:resource="Autumn"/>
    <naturopathy:hasNutrient rdf:resource="Protein"/>
</naturopathy:Food>
```

Figure 3. Dataset both in English and French

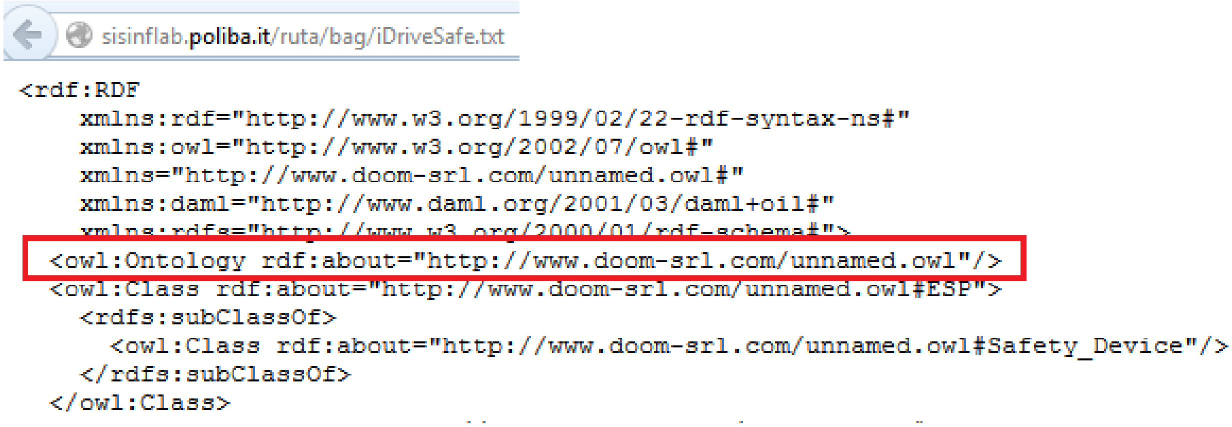
III. Add description to concepts and properties

Document domain knowledge (concepts, properties, instances) with human-friendly labels and comments (rdfs:label and rdfs:comment, dcterms:description) are recommended. In the Figure 3 you can see labels in two languages French and English.

IV. Ontology best practices

1. Choose a good namespace

As you can see in the Figure 4, the ontology does not have a good name since it is called unnamed.owl



sisinflab.poliba.it/ruta/bag/iDriveSafe.txt

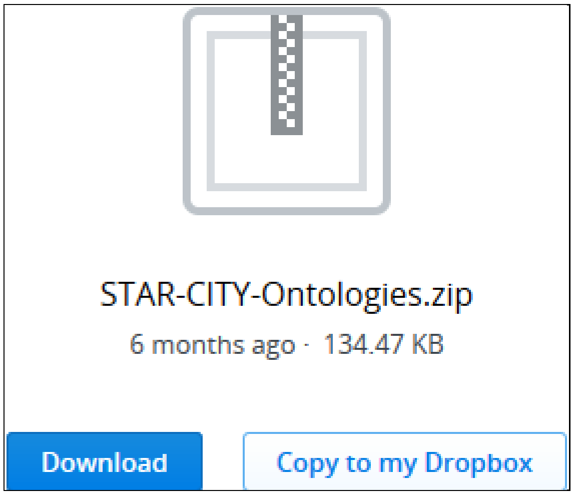
```
<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:owl="http://www.w3.org/2002/07/owl#"
    xmlns="http://www.doom-srl.com/unnamed.owl#"
    xmlns:daml="http://www.daml.org/2001/03/daml+oil#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
  <owl:Ontology rdf:about="http://www.doom-srl.com/unnamed.owl"/>
  <owl:Class rdf:about="http://www.doom-srl.com/unnamed.owl#ESP">
    <rdfs:subClassOf>
      <owl:Class rdf:about="http://www.doom-srl.com/unnamed.owl#Safety_Device"/>
    </rdfs:subClassOf>
  </owl:Class>
```

Figure 4. The ontology [32] does not have a good namespace

The **good practice** is to have the same URI for both the namespace and the ontology location as depicted in the Figure 8. This mechanism is called **URI deferencable**.

2. Publish online the ontology

Publish online the ontology on your server. The OWL file is directly accessible through the Web not in a zip file or other.



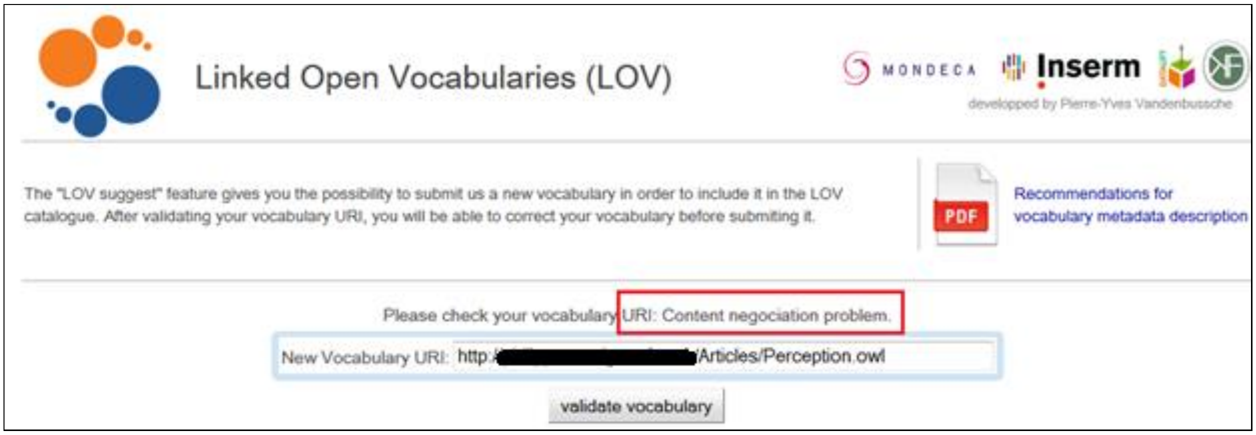
STAR-CITY-Ontologies.zip

6 months ago · 134.47 KB

Figure 5. Bad practice [20]

3. Ontology URI deferencable, Content Negociation Problem

Once the ontology is published online, the ontology can be submitted to the LOV project. Frequently, domain experts encountered the problem **Content Negociation Problem** as depicted in the Figure 6.


Linked Open Vocabularies (LOV)
MONDECA
Inserm
developped by Pierre-Yves Vandenbussche
PDF
Recommendations for vocabulary metadata description
validate vocabulary

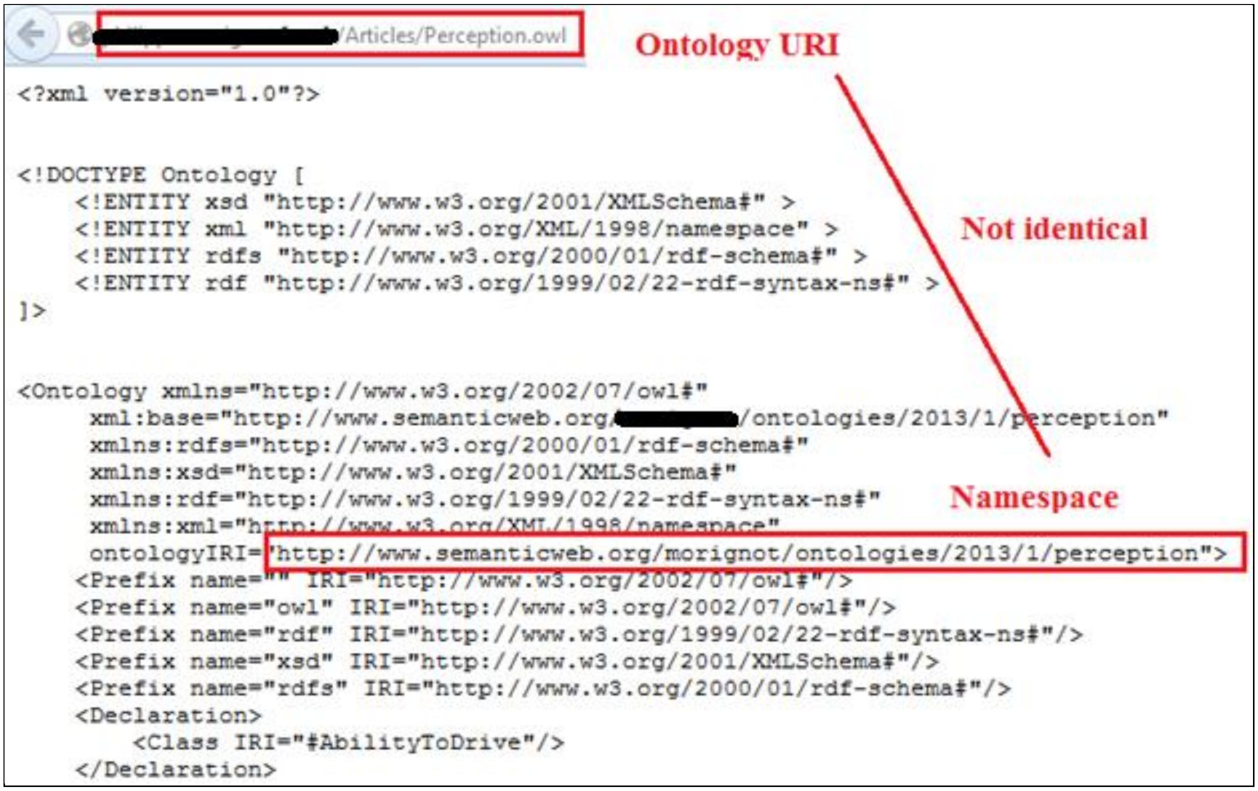
The "LOV suggest" feature gives you the possibility to submit us a new vocabulary in order to include it in the LOV catalogue. After validating your vocabulary URI, you will be able to correct your vocabulary before submiting it.

Please check your vocabulary URI: Content negociation problem.

New Vocabulary URI: http://[redacted]/Articles/Perception.owl

Figure 6. Content negociation problem

When we look up the **namespace** of the ontology on a Web browser, we should find the ontology. The namespace of the ontology should be the same that the location of the ontology, it is called **URI deferencable**. In the Figure 7, this is not the case the namespace URI and the ontology URI are not identical, this is why the LOV project generated the **context negociation** error.

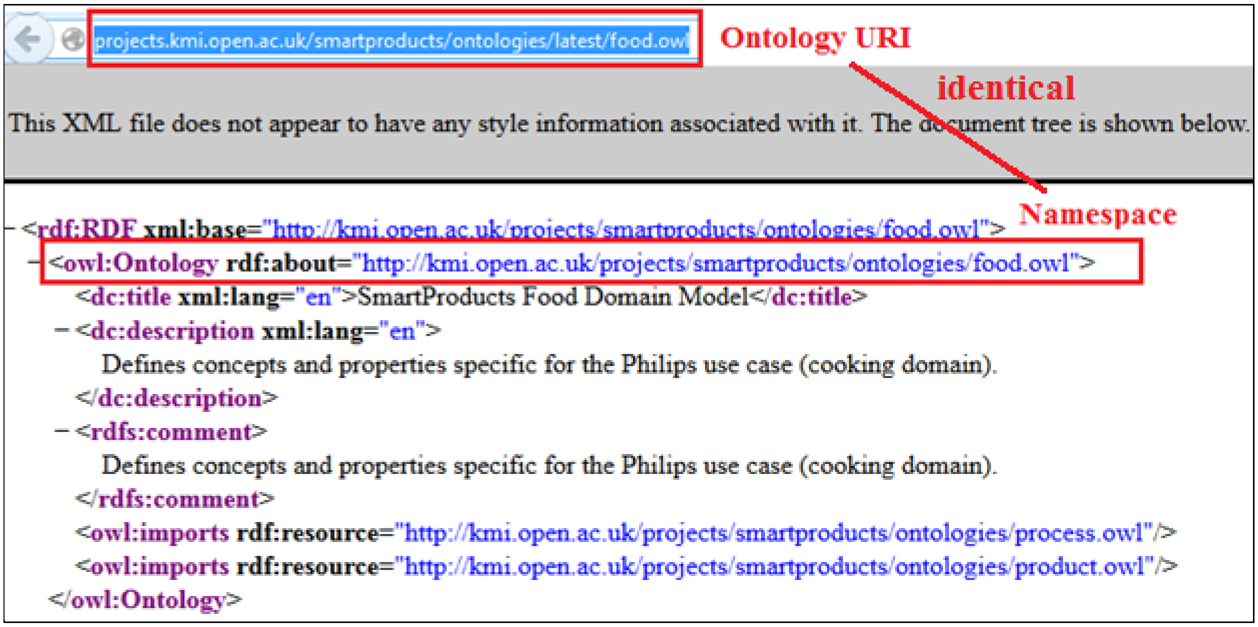


[redacted]/Articles/Perception.owl

```
<?xml version="1.0"?>


<!DOCTYPE Ontology [
    <!ENTITY xsd "http://www.w3.org/2001/XMLSchema#" >
    <!ENTITY xml "http://www.w3.org/XML/1998/namespace" >
    <!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
    <!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#" >
]>


<Ontology xmlns="http://www.w3.org/2002/07/owl#"
     xml:base="http://www.semanticweb.org[redacted]/ontologies/2013/1/perception"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:xml="http://www.w3.org/XML/1998/namespace"
     ontologyIRI="http://www.semanticweb.org/morignot/ontologies/2013/1/perception">
    <Prefix name="" IRI="http://www.w3.org/2002/07/owl#"/>
    <Prefix name="owl" IRI="http://www.w3.org/2002/07/owl#"/>
    <Prefix name="rdf" IRI="http://www.w3.org/1999/02/22-rdf-syntax-ns#"/>
    <Prefix name="xsd" IRI="http://www.w3.org/2001/XMLSchema#"/>
    <Prefix name="rdfs" IRI="http://www.w3.org/2000/01/rdf-schema#"/>
    <Declaration>
        <Class IRI="#AbilityToDrive"/>
    </Declaration>
```

Figure 7. The namespace and the ontology URI [27] are not identical

The **good practice** is to have the same URI for both the namespace and the ontology location as depicted in the Figure 8. This mechanism is called **URI deferencable**.


projects.kmi.open.ac.uk/smartproducts/ontologies/latest/food.owl
Ontology URI
identical
Namespace

This XML file does not appear to have any style information associated with it. The document tree is shown below.

```
- <rdf:RDF xml:base="http://kmi.open.ac.uk/projects/smartproducts/ontologies/food.owl">
  - <owl:Ontology rdf:about="http://kmi.open.ac.uk/projects/smartproducts/ontologies/food.owl">
      <dc:title xml:lang="en">SmartProducts Food Domain Model</dc:title>
    - <dc:description xml:lang="en">
        Defines concepts and properties specific for the Philips use case (cooking domain).
      </dc:description>
    - <rdfs:comment>
        Defines concepts and properties specific for the Philips use case (cooking domain).
      </rdfs:comment>
      <owl:imports rdf:resource="http://kmi.open.ac.uk/projects/smartproducts/ontologies/process.owl"/>
      <owl:imports rdf:resource="http://kmi.open.ac.uk/projects/smartproducts/ontologies/product.owl"/>
    </owl:Ontology>
```

Figure 8. The namespace and the ontology URI are identical

4. Linking common concepts with existing ontologies

Reuse domain knowledge rather than reinventing them:

- The ontology should reuse existing ontologies wherever possible.
- Add owl:equivalentClass for common concepts already defined in existing ontologies
- The class or properties are those from the ontologies referenced on LOV.
- Link common concept (owl:equivalentClass or rdfs:subClassOf) with well-known ontologies (e.g., Person is already described in FOAF)
- You can always extend an ontology to fit your needs

Some ontologies are not longer maintained but cannot be ignored.

This is the case for SWEET implemented by the NASA which design about 6000 concepts in 200 separate ontologies.

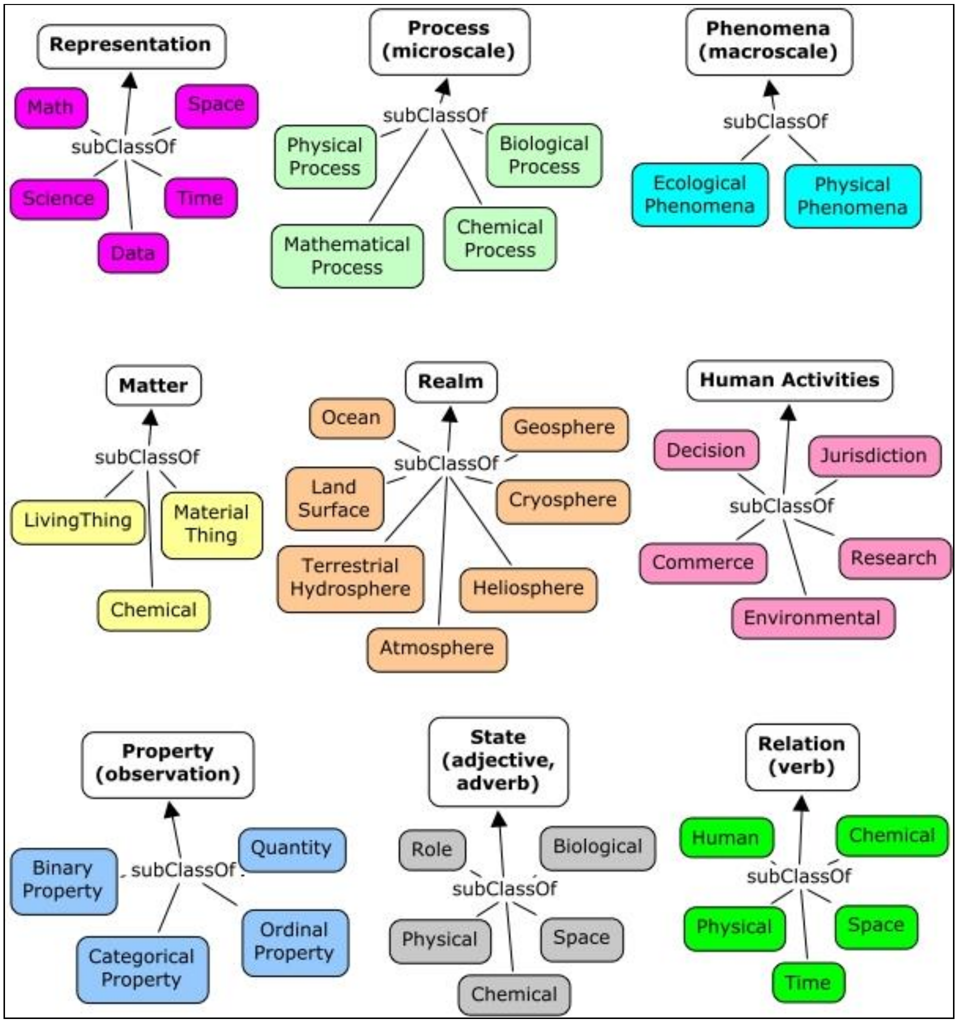


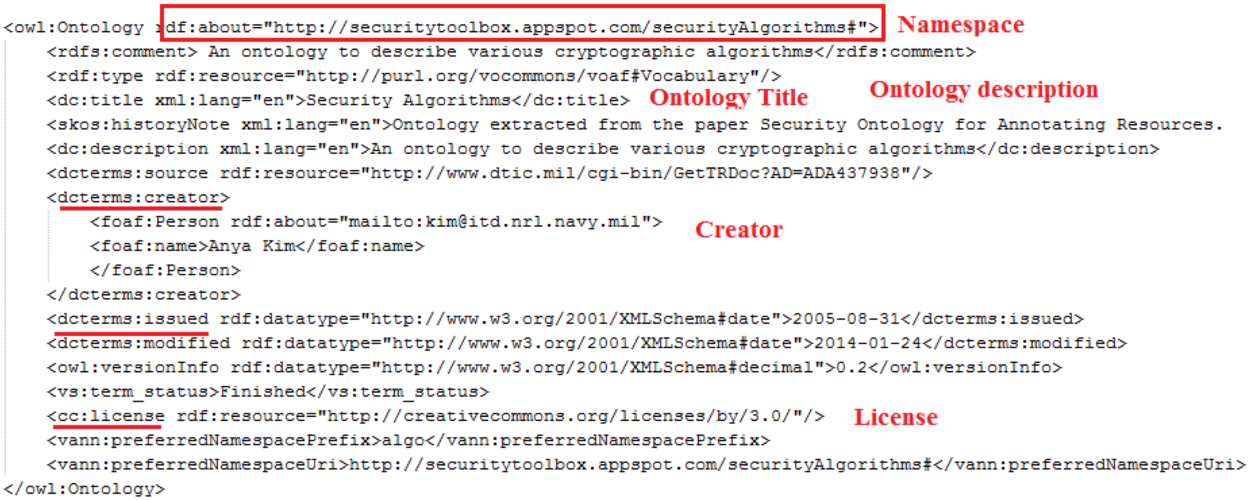
Figure 9. SWEET ontologies

Some ontologies are still maintained but is linked to ontologies which are not maintained anymore, for example the emotion ontology [13] which is based on the OBO ontology.

5. Ontology metadata: LOV recommendation

Reference your ontology on LOV(see section Ontology catalogue)

- Add ontology metadata recommended by LOV as depicted in the Figure 10
- Metadata Recommendations For Linked Open Data Vocabularies
- A code example is available (See Annexe A: Ontology LOV metadata)



```
<owl:Ontology rdf:about="http://securitytoolbox.appspot.com/securityAlgorithms#">
    <rdfs:comment> An ontology to describe various cryptographic algorithms</rdfs:comment>
    <rdf:type rdf:resource="http://purl.org/vocommons/voaf#Vocabulary"/>
    <dc:title xml:lang="en">Security Algorithms</dc:title>
    <skos:historyNote xml:lang="en">Ontology extracted from the paper Security Ontology for Annotating Resources.
    <dc:description xml:lang="en">An ontology to describe various cryptographic algorithms</dc:description>
    <dcterms:source rdf:resource="http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA437938"/>
    <dcterms:creator>
        <foaf:Person rdf:about="mailto:kim@itd.nrl.navy.mil">
        <foaf:name>Anya Kim</foaf:name>
        </foaf:Person>
    </dcterms:creator>
    <dcterms:issued rdf:datatype="http://www.w3.org/2001/XMLSchema#date">2005-08-31</dcterms:issued>
    <dcterms:modified rdf:datatype="http://www.w3.org/2001/XMLSchema#date">2014-01-24</dcterms:modified>
    <owl:versionInfo rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">0.2</owl:versionInfo>
    <vs:term_status>Finished</vs:term_status>
    <cc:license rdf:resource="http://creativecommons.org/licenses/by/3.0/"/>
    <vann:preferredNamespacePrefix>algo</vann:preferredNamespacePrefix>
    <vann:preferredNamespaceUri>http://securitytoolbox.appspot.com/securityAlgorithms#</vann:preferredNamespaceUri>
</owl:Ontology>
```

Figure 10. Ontology metadata recommended by LOV

Frequently domain experts encountered some errors when submitting their ontology to LOV.

If this is the case, check:

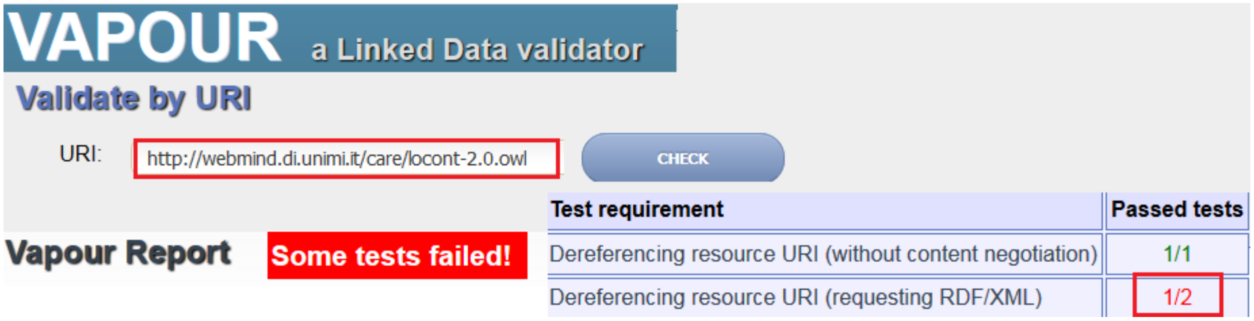
- Test the ontology URL on Vapour **Error! Reference source not found.**.
- Test the ontology URL on RDF Triple-Checker presented in **Error! Reference source not found.**
- The ontology best practices

6. Server-side configuration, Vapour

Vapour is a link data validator to check whether the data are correctly published according to the semantic web guidelines, as defined by the Linked Data principles, the Best Practice Recipes and the Cool URIs.

Vapour checks three tasks:

- 1st request while dereferencing resource URI without specifying the desired content type (HTTP response code should be 200)
- 1st request while dereferencing resource URI without specifying the desired content type (HTTP response code should be 200)
- 1st request while dereferencing resource URI without specifying the desired content type (Content type should be 'application/rdf+xml')



URI: http://webmind.di.unimi.it/care/locont-2.0.owl

Test requirement	Passed tests
Dereferencing resource URI (without content negotiation)	1/1
Dereferencing resource URI (requesting RDF/XML)	1/2

Figure 11. Vapour tool failed with [30]

Riboni et al. [30] have to correct the error “1st request while dereferencing resource URI without specifying the desired content type (Content type should be 'application/rdf+xml'): Failed”.

The solution is to configure the server. For instance for Apache server you can change the httpd.conf configuration file and add the following line.

```
AddType application:rdf+xml .rdf
```

Or you can add this information in the .htaccess file in the directory on the server where the RDF files are placed.

This is a main issue to achieve this task, since some authors share their ontologies:

- On a personal web page, they cannot control the server
- Use google app engine

Kenfack et al. [17] try to host their ontologies on GitHub, it was a good idea, but it generates an error on Vapour:

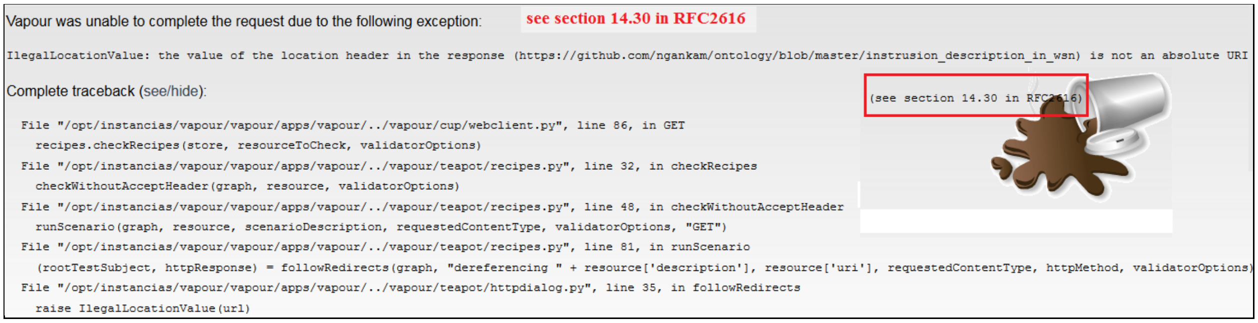
```
IlegalLocationValue: the value of the location header in the response
(https://github.com/ngankam/ontology/blob/master/instrusion_description_in_ws
n) is not an absolute URI (see the RFC 2616, section 14.30)
```

https://tools.ietf.org/html/rfc2616

14.30 Location

```
   The Location response-header field is used to redirect the recipient
   to a location other than the Request-URI for completion of the
   request or identification of a new resource. For 201 (Created)
   responses, the Location is that of the new resource which was created
   by the request. For 3xx responses, the location SHOULD indicate the
   server's preferred URI for automatic redirection to the resource. The
   field value consists of a single absolute URI.
```

```
    Location       = "Location" ":" absoluteURI

An example is:

    Location: http://www.w3.org/pub/WWW/People.html

   Note: The Content-Location header field (section 14.14) differs
   from Location in that the Content-Location identifies the original
   location of the entity enclosed in the request. It is therefore
   possible for a response to contain header fields for both Location
   and Content-Location. Also see section 13.10 for cache
   requirements of some methods.
```



Vapour was unable to complete the request due to the following exception: see section 14.30 in RFC2616

```
IlegalLocationValue: the value of the location header in the response (https://github.com/ngankam/ontology/blob/master/instrusion_description_in_wsn) is not an absolute URI
```

Complete traceback (see/hide):

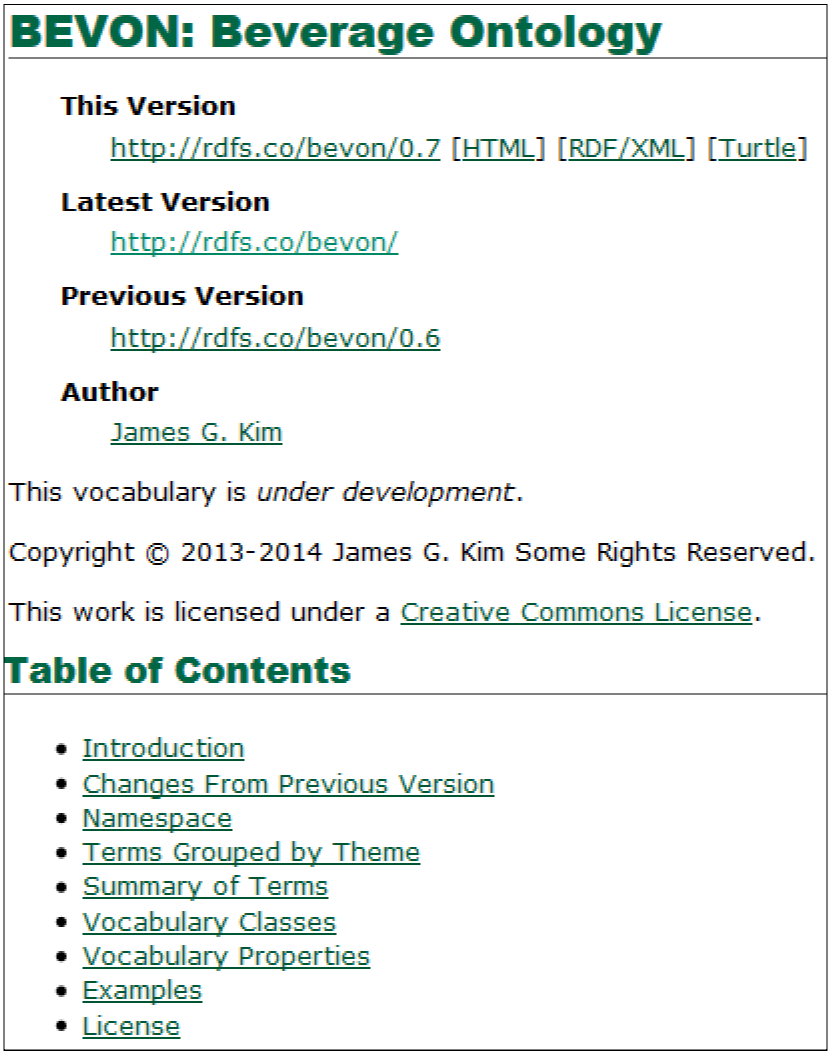
```
  File "/opt/instancias/vapour/vapour/apps/vapour/../vapour/cup/webclient.py", line 86, in GET
    recipes.checkRecipes(store, resourceToCheck, validatorOptions)
  File "/opt/instancias/vapour/vapour/apps/vapour/../vapour/teapot/recipes.py", line 32, in checkRecipes
    checkWithoutAcceptHeader(graph, resource, validatorOptions)
  File "/opt/instancias/vapour/vapour/apps/vapour/../vapour/teapot/recipes.py", line 48, in checkWithoutAcceptHeader
    runScenario(graph, resource, scenarioDescription, requestedContentType, validatorOptions, "GET")
  File "/opt/instancias/vapour/vapour/apps/vapour/../vapour/teapot/recipes.py", line 81, in runScenario
    (rootTestSubject, httpResponse) = followRedirects(graph, "dereferencing " + resource['description'], resource['uri'], requestedContentType, httpMethod, validatorOptions)
  File "/opt/instancias/vapour/vapour/apps/vapour/../vapour/teapot/httpdialog.py", line 35, in followRedirects
    raise IlegalLocationValue(url)
```

(see section 14.30 in RFC2616)

Figure 12. Vapour error indicates to see the RFC 2616, section 14.30

7. Provide an ontology documentation

- Parrot is a web service, there is nothing to install. Less than 30 minutes to add a documentation to your dataset or ontology.
- Neologism. Need to install the software
- SpecGen . Need to install the software



BEVON: Beverage Ontology

This Version

http://rdfs.co/bevon/0.7 [HTML] [RDF/XML] [Turtle]

Latest Version

http://rdfs.co/bevon/

Previous Version

http://rdfs.co/bevon/0.6

Author

James G. Kim

This vocabulary is *under development*.

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- Changes From Previous Version
- Namespace
- Terms Grouped by Theme
- Summary of Terms
- Vocabulary Classes
- Vocabulary Properties
- Examples
- License

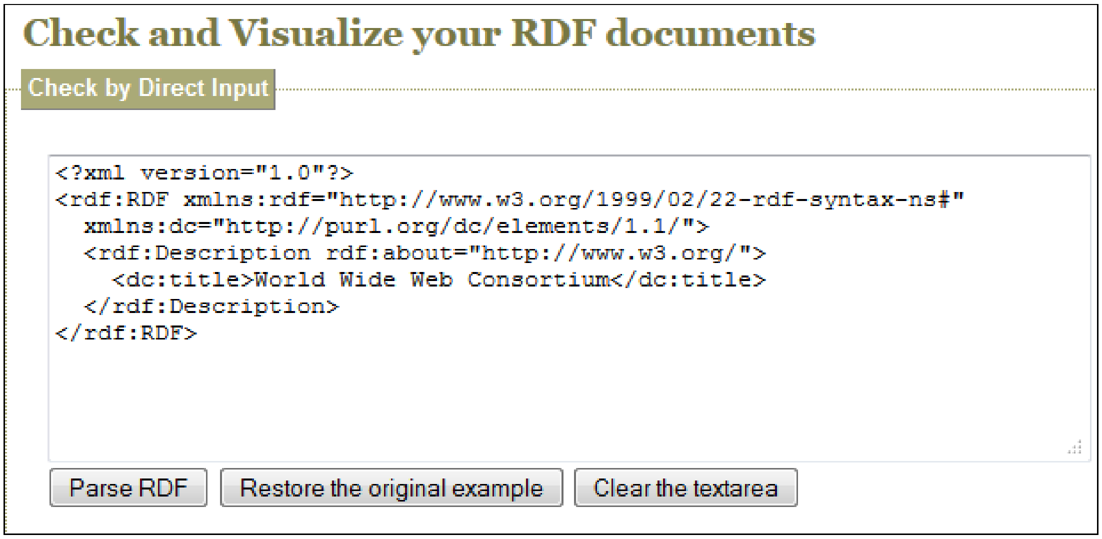
Figure 13. Documentation example

8. Validate your ontology with semantic web validators

They are more and more tools implemented by the semantic web community to detect common errors when developing your RDF data or ontologies.

- RDF Validator is used to check your RDF documents as depicted in the Figure 14.
- OWL Validator is used to check your OWL documents.
- OOPS! (OntOlogy Pitfall Scanner!) is a tool to detect common ontology errors as depicted in the Figure 15.
- The RDF Triple-Checker tool helps find typos and common errors in RDF data
- Vapour is a link data validator to check whether the data are correctly published according to the semantic web guidelines, as defined by the Linked Data principles, the Best Practice Recipes and the Cool URIs.

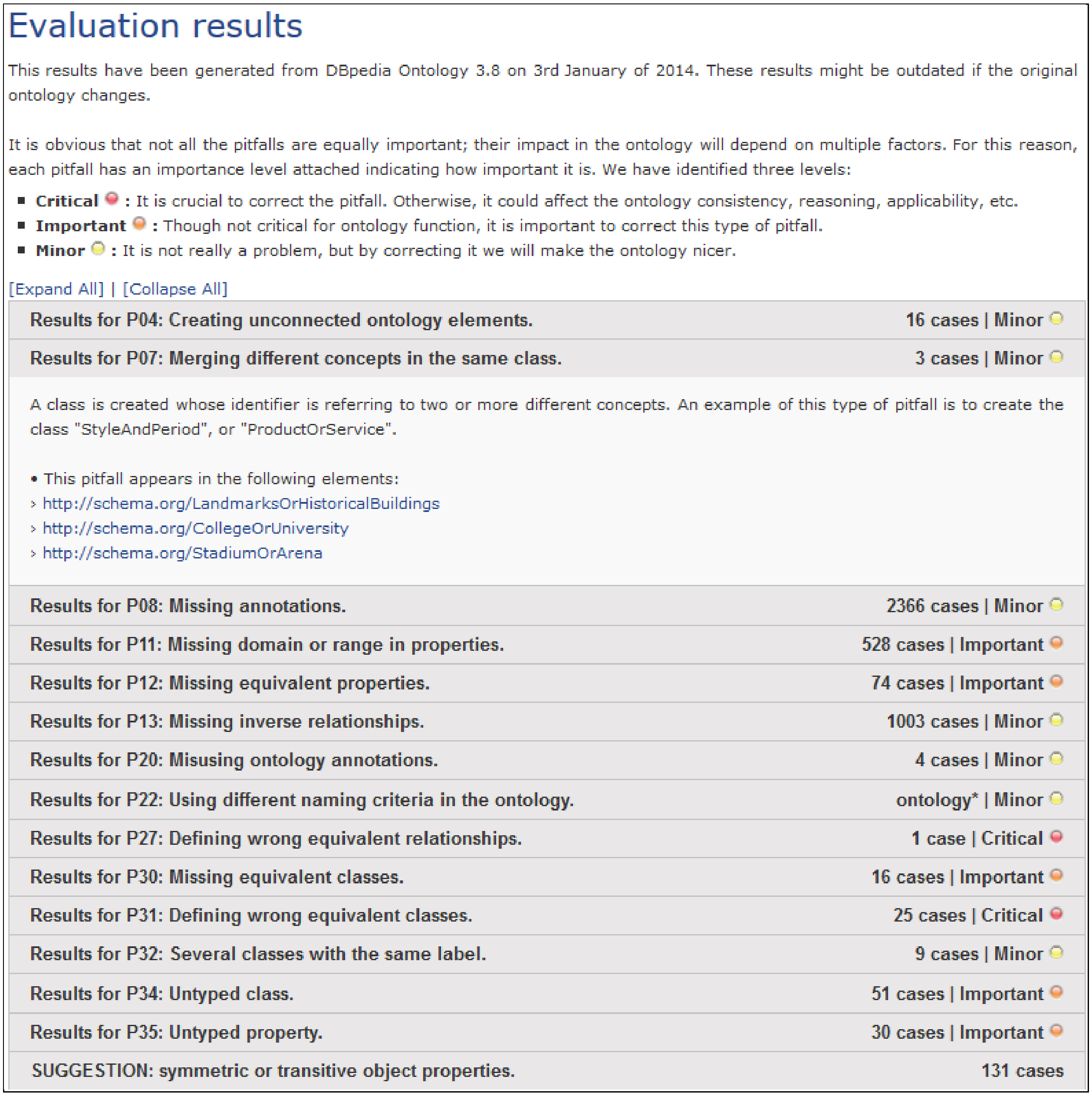
- RDFAbout is a RDF Validator and Converter between the RDF/XML format and N3 (Notation 3 or N-Triples Turtle).


Check and Visualize your RDF documents
Check by Direct Input

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:dc="http://purl.org/dc/elements/1.1/">
  <rdf:Description rdf:about="http://www.w3.org/">
    <dc:title>World Wide Web Consortium</dc:title>
  </rdf:Description>
</rdf:RDF>
```

Parse RDF
Restore the original example
Clear the textarea

Figure 14. RDF validator



Evaluation results

This results have been generated from DBpedia Ontology 3.8 on 3rd January of 2014. These results might be outdated if the original ontology changes.

It is obvious that not all the pitfalls are equally important; their impact in the ontology will depend on multiple factors. For this reason, each pitfall has an importance level attached indicating how important it is. We have identified three levels:

- **Critical** 🔴 **:** It is crucial to correct the pitfall. Otherwise, it could affect the ontology consistency, reasoning, applicability, etc.
- **Important** 🟠 **:** Though not critical for ontology function, it is important to correct this type of pitfall.
- **Minor** 🟡 **:** It is not really a problem, but by correcting it we will make the ontology nicer.

[Expand All] | [Collapse All]

Results for P04: Creating unconnected ontology elements.	16 cases | Minor 🟡
Results for P07: Merging different concepts in the same class.	3 cases | Minor 🟡

A class is created whose identifier is referring to two or more different concepts. An example of this type of pitfall is to create the class "StyleAndPeriod", or "ProductOrService".

• This pitfall appears in the following elements:
› http://schema.org/LandmarksOrHistoricalBuildings
› http://schema.org/CollegeOrUniversity
› http://schema.org/StadiumOrArena

Results for P08: Missing annotations.	2366 cases | Minor 🟡
Results for P11: Missing domain or range in properties.	528 cases | Important 🟠
Results for P12: Missing equivalent properties.	74 cases | Important 🟠
Results for P13: Missing inverse relationships.	1003 cases | Minor 🟡
Results for P20: Misusing ontology annotations.	4 cases | Minor 🟡
Results for P22: Using different naming criteria in the ontology.	ontology* | Minor 🟡
Results for P27: Defining wrong equivalent relationships.	1 case | Critical 🔴
Results for P30: Missing equivalent classes.	16 cases | Important 🟠
Results for P31: Defining wrong equivalent classes.	25 cases | Critical 🔴
Results for P32: Several classes with the same label.	9 cases | Minor 🟡
Results for P34: Untyped class.	51 cases | Important 🟠
Results for P35: Untyped property.	30 cases | Important 🟠
SUGGESTION: symmetric or transitive object properties.	131 cases

Figure 15. The Oops tool detects errors when developing ontologies

V. Dataset best practices

Publish your data:

- D2R server enables to publish your database schema as a SPARQL endpoint.
- Jena fuseki
- SPARQL endpoint

- Reference your dataset on DataHub and other related tools (see section Dataset catalogue).

Linked Data is about using the Web to connect related data that wasn't previously linked, or using the Web to lower the barriers to linking data currently linked using other methods.

Linked Open Data

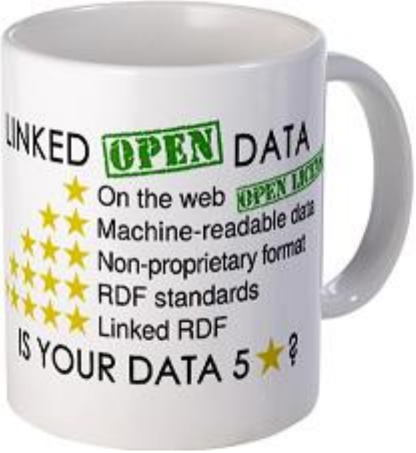


Figure 16. Linked Open Data Best practices

- How to Publish Linked Data on the Web

Linked Data (design issues)

Publishing descriptions of a data set:

- Semantic SiteMap to add metadata to the dataset (e.g., sparql endpoint)
- void (Vocabulary of Interlinked Datasets) is a standard vocabulary for describing datasets

To digitally sign your data you can use the NG4J, a Named Graphs API for Jena.

Chapter 3. Ontology interoperability

- Protégé is the most used ontology free editor tool to design a new ontology as depicted in the Figure 32 and proposes various plugin for ontology visualization, writting rules, etc.
- Callimachus
- SWOOP is a tool for creating, editing, and debugging OWL ontologies.
- Jena compatible with JAVA
- Virtuoso
- Sesame
- NeOn Toolkit

I. Protégé

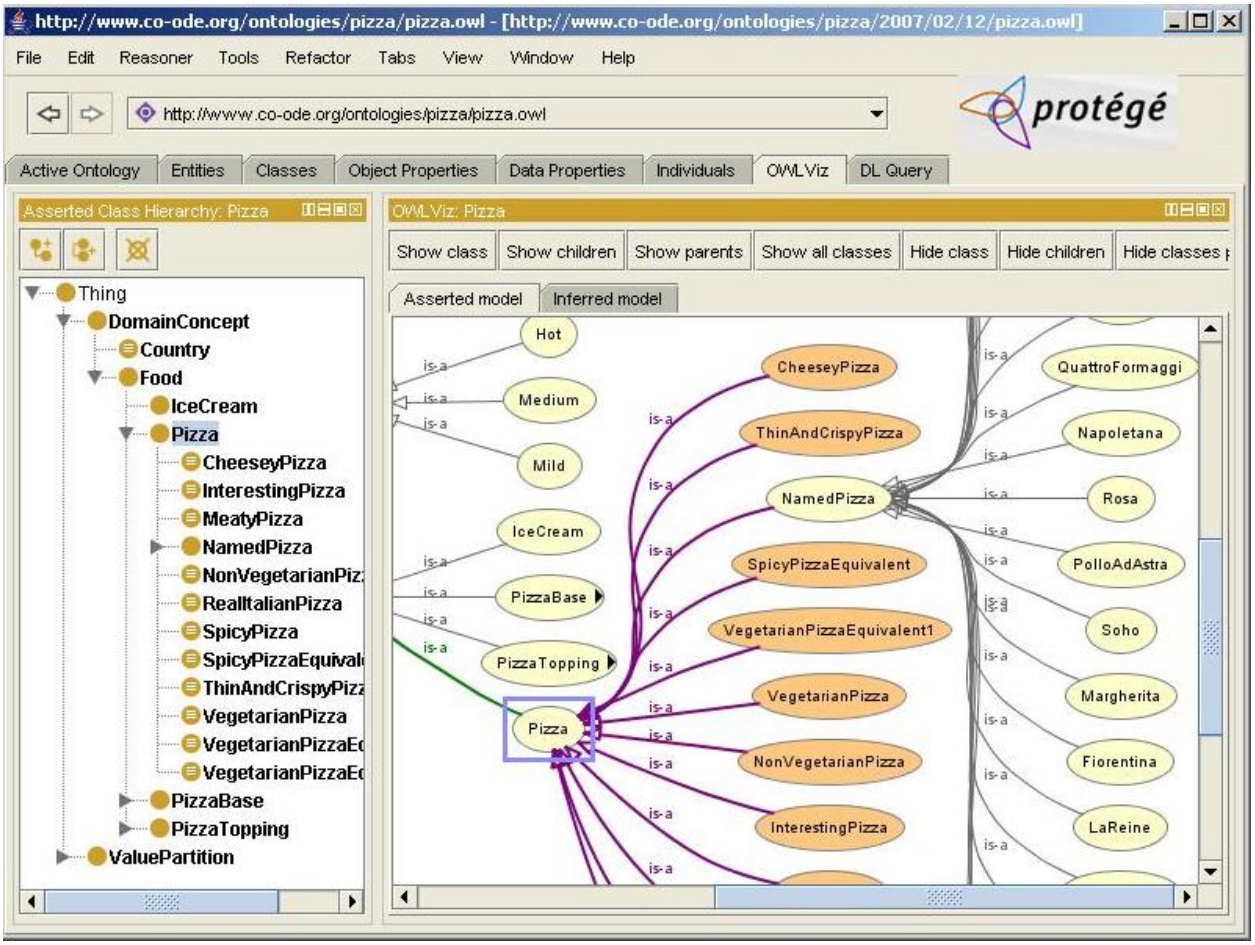
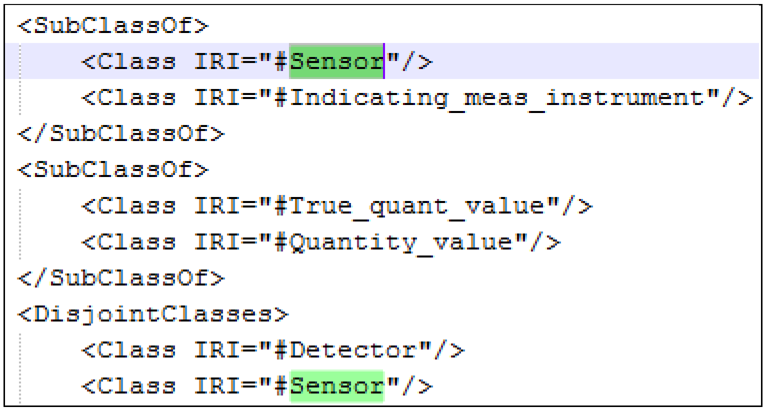


Figure 17. Protégé Editor tool

II. OWL API

OWL API as depicted in the Figure 33

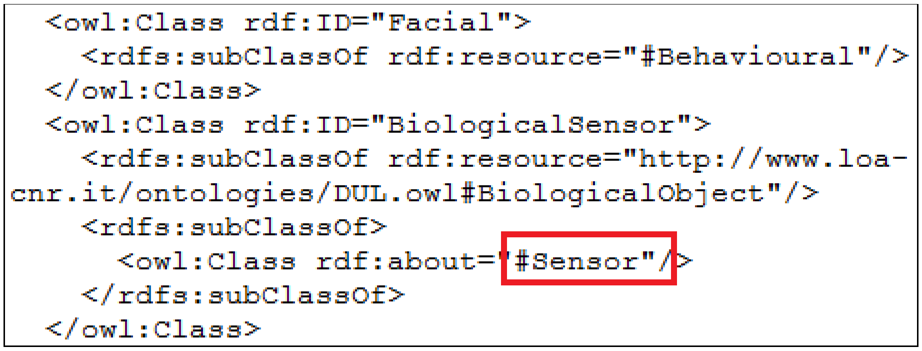


```
<SubClassOf>
    <Class IRI="#Sensor"/>
    <Class IRI="#Indicating_meas_instrument"/>
</SubClassOf>
<SubClassOf>
    <Class IRI="#True_quant_value"/>
    <Class IRI="#Quantity_value"/>
</SubClassOf>
<DisjointClasses>
    <Class IRI="#Detector"/>
    <Class IRI="#Sensor"/>
```

Figure 18. Ontology designed with OWL API [4]

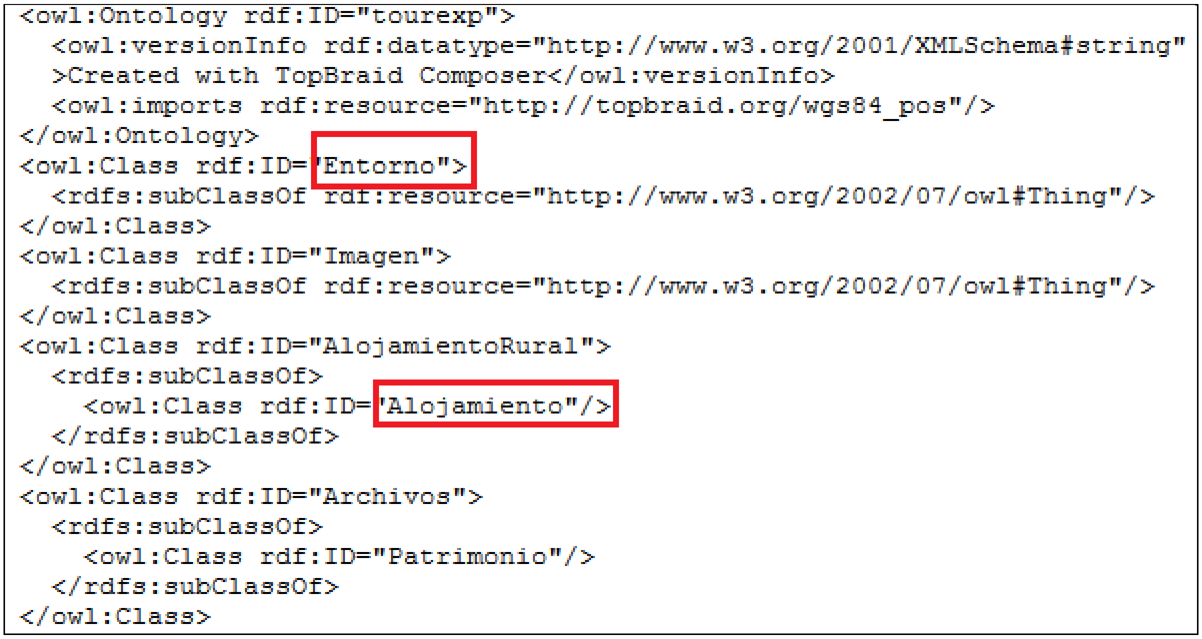
III. TopBraid

TopBraid is a commercial solution to build semantic web and linked data applications



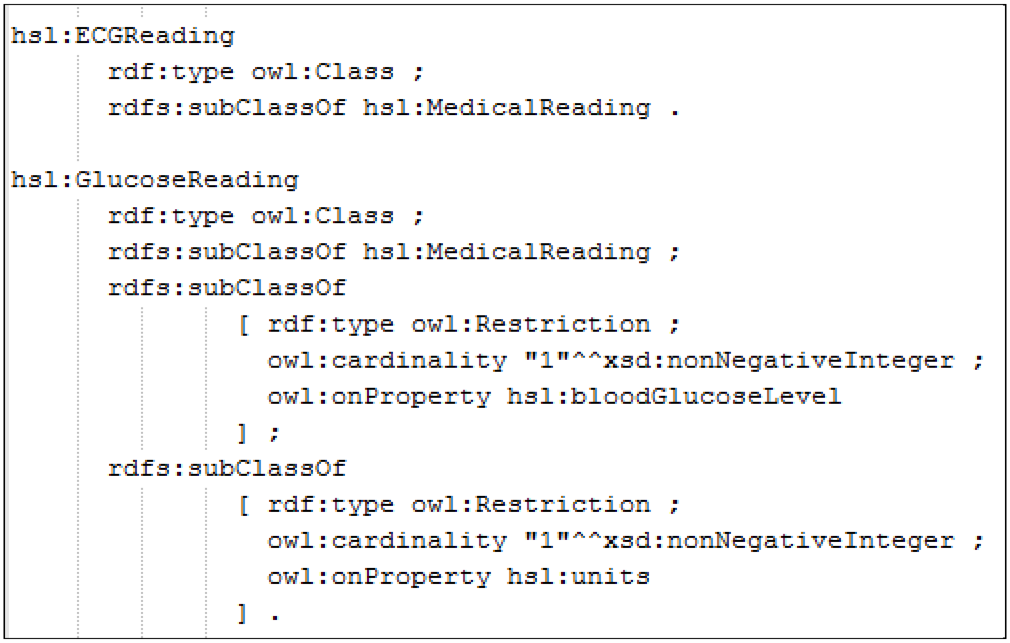
```
  <owl:Class rdf:ID="Facial">
    <rdfs:subClassOf rdf:resource="#Behavioural"/>
  </owl:Class>
  <owl:Class rdf:ID="BiologicalSensor">
    <rdfs:subClassOf rdf:resource="http://www.loa-
cnr.it/ontologies/DUL.owl#BiologicalObject"/>
    <rdfs:subClassOf>
      <owl:Class rdf:about="#Sensor"/>
    </rdfs:subClassOf>
  </owl:Class>
```

Figure 19. Lopez et al. designed an emotion ontology [21] with TopBraid



```
<owl:Ontology rdf:ID="tourexp">
  <owl:versionInfo rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >Created with TopBraid Composer</owl:versionInfo>
  <owl:imports rdf:resource="http://topbraid.org/wgs84_pos"/>
</owl:Ontology>
<owl:Class rdf:ID="Entorno">
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
</owl:Class>
<owl:Class rdf:ID="Imagen">
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
</owl:Class>
<owl:Class rdf:ID="AlojamientoRural">
  <rdfs:subClassOf>
    <owl:Class rdf:ID="Alojamiento"/>
  </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:ID="Archivos">
  <rdfs:subClassOf>
    <owl:Class rdf:ID="Patrimonio"/>
  </rdfs:subClassOf>
</owl:Class>
```

Figure 20. Bujan et al. designed a tourism ontology with TopBraid and the rdf/xml syntax [2] and not in english



```
hsl:ECGReading
      rdf:type owl:Class ;
      rdfs:subClassOf hsl:MedicalReading .

hsl:GlucoseReading
      rdf:type owl:Class ;
      rdfs:subClassOf hsl:MedicalReading ;
      rdfs:subClassOf
              [ rdf:type owl:Restriction ;
                owl:cardinality "1"^^xsd:nonNegativeInteger ;
                owl:onProperty hsl:bloodGlucoseLevel
              ] ;
      rdfs:subClassOf
              [ rdf:type owl:Restriction ;
                owl:cardinality "1"^^xsd:nonNegativeInteger ;
                owl:onProperty hsl:units
              ] .
```

Figure 21. Henessy, Ray et al. designed an emotion ontology with TopBraid and the turtle syntax [15]

Chapter 4. Rules interoperability

There is a need to work on the interoperability of the different implementation of ontologies and rules generated by software and semantic tools.

Various languages have been referenced to describe the semantic web rules:

- SWRL (Semantic Web Rule Language) is frequently used by domain experts since it is easy to use and already implemented by software. **This language is not advocated by the semantic web community.**
- SPIN (SPARQL Inferencing Notation) is **advocated by semantic web experts since it is a W3C recommendation since 2013.**
- RIF (Rule Interchange Format). Usual software used by domain experts do not implement RIF.
- Rules describes as restriction in the ontologies

I. OWL rules interoperability

Frequently rules are directly described as restrictions in ontologies.

Example how to combine rules related to the same concept snow:

Rule 1 (smart home domain): Snowy = belowOrZeroTemperature and Precipitation [18] [29] (Figure 23)

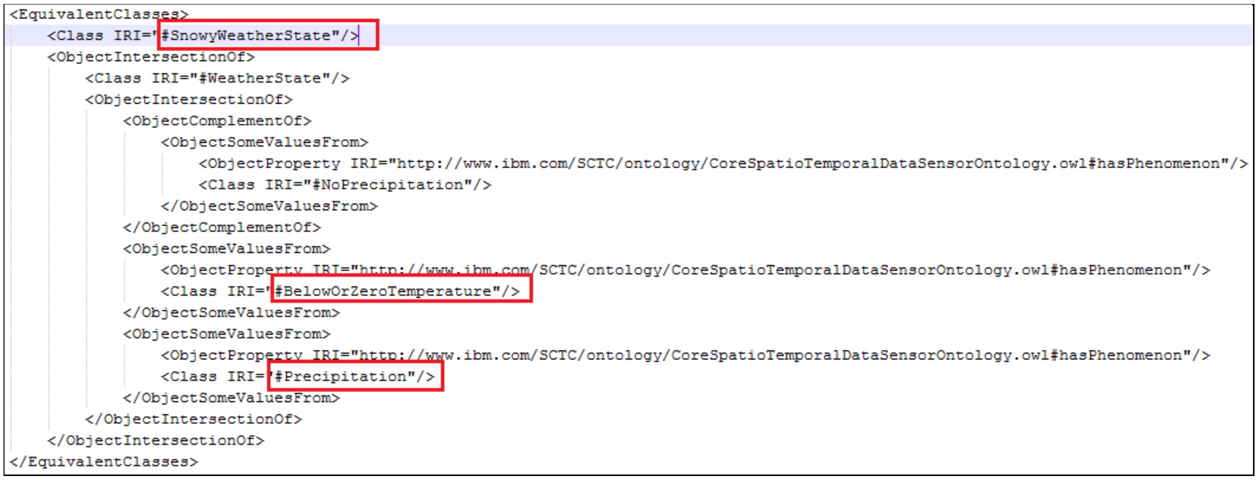
Rule 2 (smart city domain): Snowy = belowOrZeroTemperature and Precipitation [20] (Figure 23)

Rule 3 (transport domain): Snow -> safety device abs, esp, and snow chains [31] (Figure 24)

Interoperability issues:

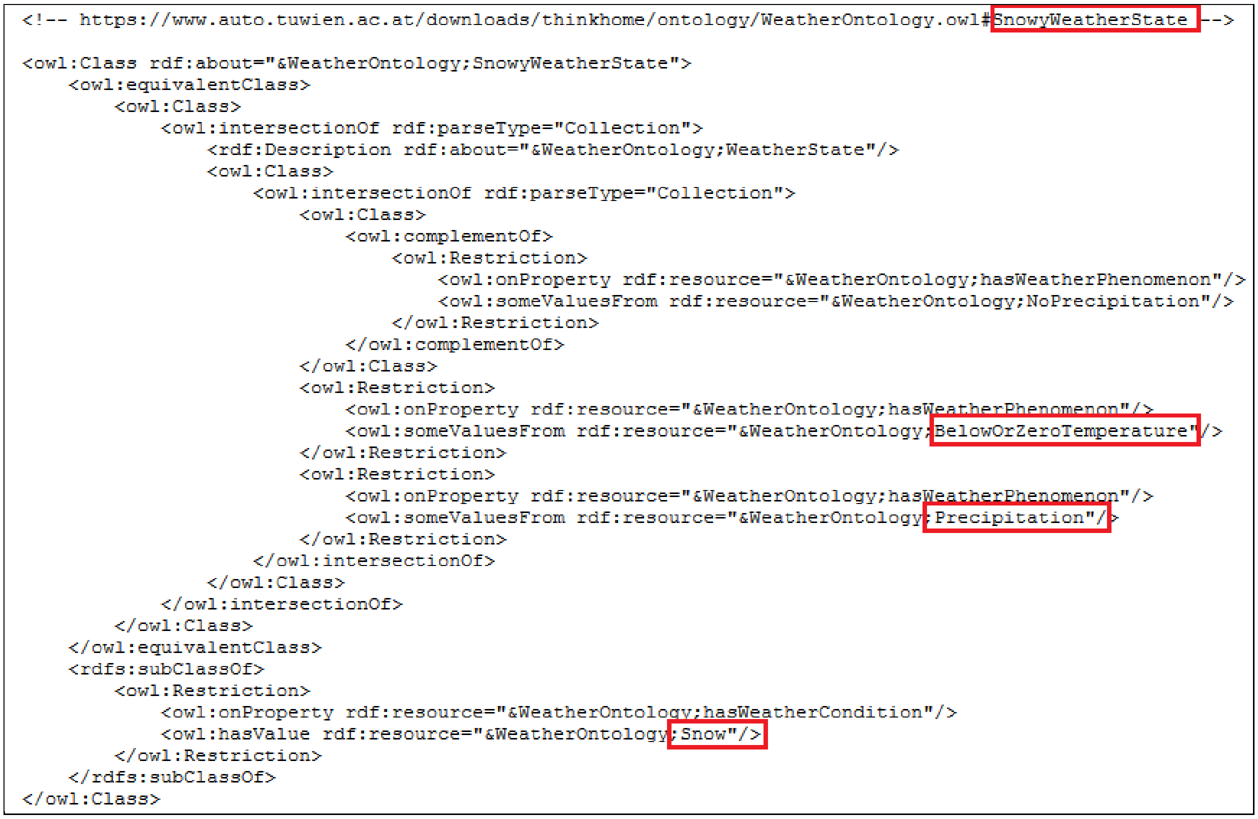
In this domain, it is called snowy in the rule 1 and snow in the rule2.

Syntax not identic



```
<EquivalentClasses>
    <Class IRI="#SnowyWeatherState"/>
    <ObjectIntersectionOf>
        <Class IRI="#WeatherState"/>
        <ObjectIntersectionOf>
            <ObjectComplementOf>
                <ObjectSomeValuesFrom>
                    <ObjectProperty IRI="http://www.ibm.com/SCTC/ontology/CoreSpatioTemporalDataSensorOntology.owl#hasPhenomenon"/>
                    <Class IRI="#NoPrecipitation"/>
                </ObjectSomeValuesFrom>
            </ObjectComplementOf>
            <ObjectSomeValuesFrom>
                <ObjectProperty IRI="http://www.ibm.com/SCTC/ontology/CoreSpatioTemporalDataSensorOntology.owl#hasPhenomenon"/>
                <Class IRI="#BelowOrZeroTemperature"/>
            </ObjectSomeValuesFrom>
            <ObjectSomeValuesFrom>
                <ObjectProperty IRI="http://www.ibm.com/SCTC/ontology/CoreSpatioTemporalDataSensorOntology.owl#hasPhenomenon"/>
                <Class IRI="#Precipitation"/>
            </ObjectSomeValuesFrom>
        </ObjectIntersectionOf>
    </ObjectIntersectionOf>
</EquivalentClasses>
```

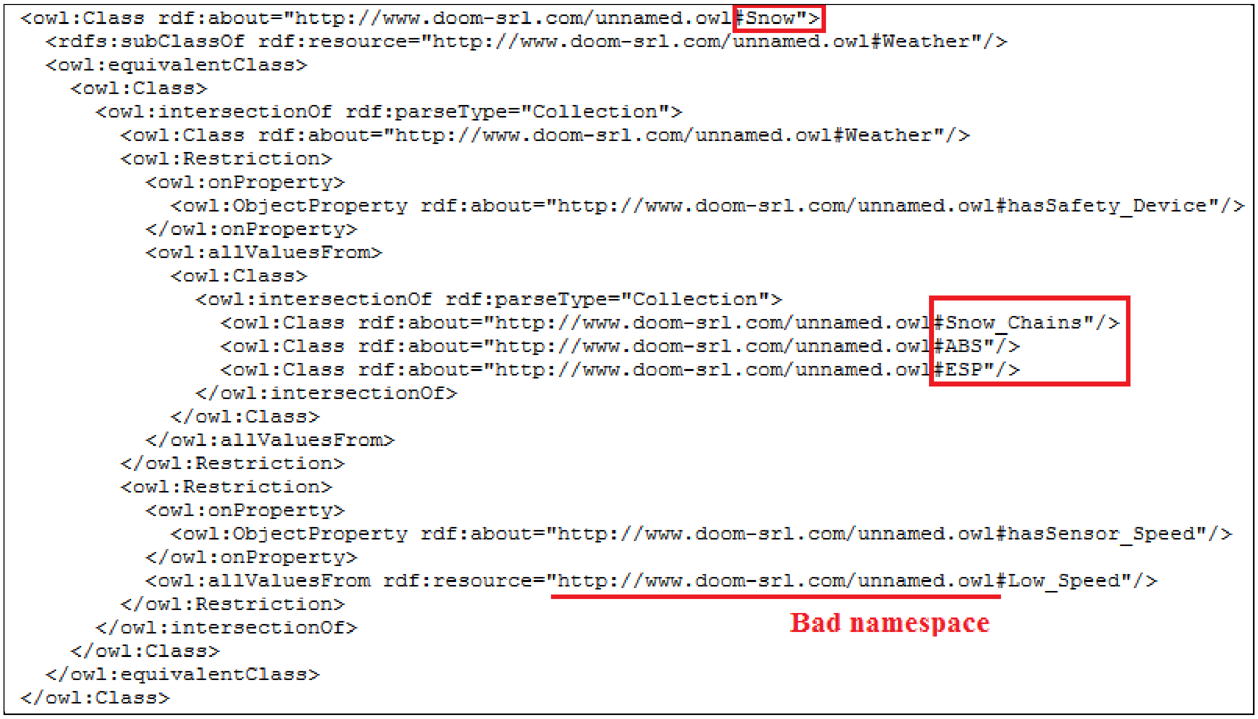
Figure 22. Snowy = belowOrZeroTemperature and Precipitation [20]



```
<!-- https://www.auto.tuwien.ac.at/downloads/thinkhome/ontology/WeatherOntology.owl#SnowyWeatherState -->

<owl:Class rdf:about="&WeatherOntology;SnowyWeatherState">
    <owl:equivalentClass>
        <owl:Class>
            <owl:intersectionOf rdf:parseType="Collection">
                <rdf:Description rdf:about="&WeatherOntology;WeatherState"/>
                <owl:Class>
                    <owl:intersectionOf rdf:parseType="Collection">
                        <owl:Class>
                            <owl:complementOf>
                                <owl:Restriction>
                                    <owl:onProperty rdf:resource="&WeatherOntology;hasWeatherPhenomenon"/>
                                    <owl:someValuesFrom rdf:resource="&WeatherOntology;NoPrecipitation"/>
                                </owl:Restriction>
                            </owl:complementOf>
                        </owl:Class>
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="&WeatherOntology;hasWeatherPhenomenon"/>
                            <owl:someValuesFrom rdf:resource="&WeatherOntology;BelowOrZeroTemperature"/>
                        </owl:Restriction>
                        <owl:Restriction>
                            <owl:onProperty rdf:resource="&WeatherOntology;hasWeatherPhenomenon"/>
                            <owl:someValuesFrom rdf:resource="&WeatherOntology;Precipitation"/>
                        </owl:Restriction>
                    </owl:intersectionOf>
                </owl:Class>
            </owl:intersectionOf>
        </owl:Class>
    </owl:equivalentClass>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="&WeatherOntology;hasWeatherCondition"/>
            <owl:hasValue rdf:resource="&WeatherOntology;Snow"/>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
```

Figure 23. Snowy = belowOrZeroTemperature and Precipitation [18] [29]



```
<owl:Class rdf:about="http://www.doom-srl.com/unnamed.owl#Snow">
  <rdfs:subClassOf rdf:resource="http://www.doom-srl.com/unnamed.owl#Weather"/>
  <owl:equivalentClass>
    <owl:Class>
      <owl:intersectionOf rdf:parseType="Collection">
        <owl:Class rdf:about="http://www.doom-srl.com/unnamed.owl#Weather"/>
        <owl:Restriction>
          <owl:onProperty>
            <owl:ObjectProperty rdf:about="http://www.doom-srl.com/unnamed.owl#hasSafety_Device"/>
          </owl:onProperty>
          <owl:allValuesFrom>
            <owl:Class>
              <owl:intersectionOf rdf:parseType="Collection">
                <owl:Class rdf:about="http://www.doom-srl.com/unnamed.owl#Snow_Chains"/>
                <owl:Class rdf:about="http://www.doom-srl.com/unnamed.owl#ABS"/>
                <owl:Class rdf:about="http://www.doom-srl.com/unnamed.owl#ESP"/>
              </owl:intersectionOf>
            </owl:Class>
          </owl:allValuesFrom>
        </owl:Restriction>
        <owl:Restriction>
          <owl:onProperty>
            <owl:ObjectProperty rdf:about="http://www.doom-srl.com/unnamed.owl#hasSensor_Speed"/>
          </owl:onProperty>
          <owl:allValuesFrom rdf:resource="http://www.doom-srl.com/unnamed.owl#Low_Speed"/>
        </owl:Restriction>
      </owl:intersectionOf>
    </owl:Class>
  </owl:equivalentClass>
</owl:Class>
```

Bad namespace

Figure 24. Snow -> safety device abs, esp, and snow chains [31]

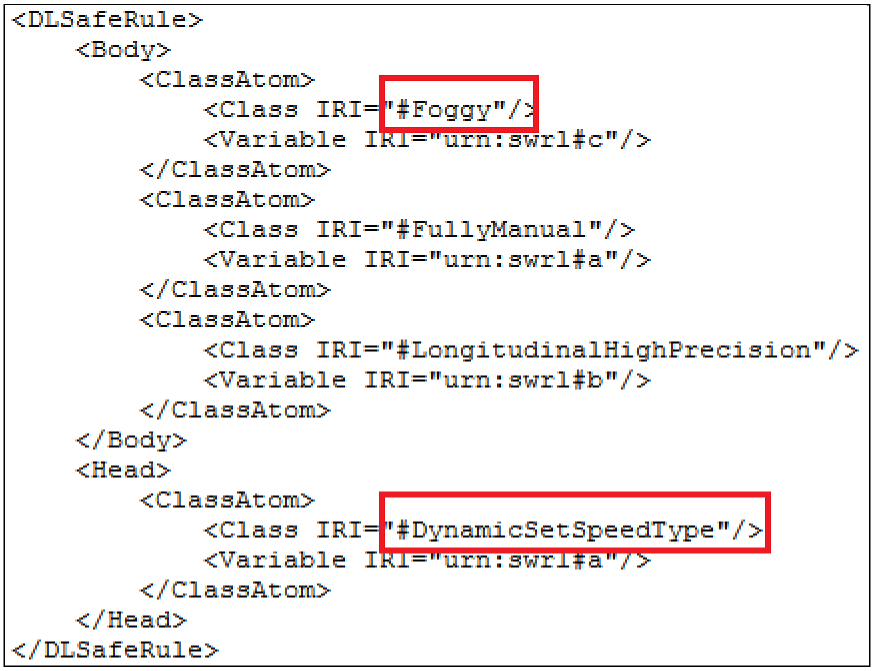
II. SWRL

SWRL (Semantic Web Rule Language) is the most popular rule language since it is easy to use and used by domain experts. **This language is not advocated by the semantic web community.** Unfortunately, the syntax varying according to the software or inference engine employed (OWL restrictions in the ontology, Jena, SWRL Tab protege, Pellet, Fact++, etc.):

- JenaRules, JenaRules wiki
- SWRL Tab (Plugin Protege) [O'Connor 2006]
- SWRL DL Safe Rule that restricts rules to operate on only known individuals of ontology.
- SWRLJess Tab (Plugin Protege)
- SWRL-IQ (Plugin Protege)
- SQWRL (Plugin Protege)
- SWRLDroolsTab (Plugin Protege)

1. SWRL and DLSafeRule

SWRL DL Safe Rule restricts rules to operate on only known individuals of ontology.
These SWRL rules are developed with the SWOOPS tool. The syntax is again different.



```
<DLSafeRule>
    <Body>
        <ClassAtom>
            <Class IRI="#Foggy"/>
            <Variable IRI="urn:swrl#c"/>
        </ClassAtom>
        <ClassAtom>
            <Class IRI="#FullyManual"/>
            <Variable IRI="urn:swrl#a"/>
        </ClassAtom>
        <ClassAtom>
            <Class IRI="#LongitudinalHighPrecision"/>
            <Variable IRI="urn:swrl#b"/>
        </ClassAtom>
    </Body>
    <Head>
        <ClassAtom>
            <Class IRI="#DynamicSetSpeedType"/>
            <Variable IRI="urn:swrl#a"/>
        </ClassAtom>
    </Head>
</DLSafeRule>
```

Figure 25. Morignot et al. [26] [23]

III. SPIN

SPIN (SPARQL Inferencing Notation) is **advocated by semantic web experts:**

- Jena SPIN rules (Jena ARQ API)
- SPIN SPARQL syntax
- SPARQL CONSTUCT (equivalent to SWRL rules)
- SPINMap

- SPARQL Motion

IV. RIF

RIF (Rule Interchange Format). Usual software used by domain experts do not implement RIF:

- RIF2SPARQL [Oumy Seye et al. 2012]
- RIF validator [Oumy Seye et al. 2012]
- Paper: R2RIF - Rule Integration Plugin for Protege OWL [Pomarolli et al. 2012] - No plugin found
- RIF implementations

Chapter 5. Domain ontologies interesting for the OneM2M uses cases

We referenced domain ontologies which could be reused for the use cases. The following ontologies are available and authors are improving the ontologies according to the semantic web guidelines. To find the corresponding ontology URL or more ontologies, you can search on this web page: http://www.sensormeasurement.appspot.com/?p=ontologies and the LOV project (http://lov.okfn.org/dataset/lov/).

I. Building Automation Ontologies

Bonino et al. [3] design the DogOnt ontology[1], referenced by LOV, this is one of the first ontology respecting the semantic web guidelines in the building automation domain. They describe the following concepts:

- Building environment (`Room` in a house such as `Bathroom, Bedroom, DiningRoom, Kitchen, LivingRoom, Lobby, StorageRoom`)
- Building thing: controllable (`fridge, oven, coffee maker, alarm clock, printer`) or not (`wall, floor`).
- Functionality (`temperature regulation, light regulation`)
- State (`temperature state, light intensity state, on/off state, open/close state`)
- `{Humidity, Temperature, Pressure} MeasurementNotification`

Staroch design an ontology smart home + weather [33] is referenced by LOV too.

Riboni [30] [14]:

[1] http://elite.polito.it/ontologies/dogont.owl

- Concepts: activity (bathing, brushing teeth, combing hair, eating, showering, sleeping), building, bus, car, carnaval party, clothing, beach, river, road, bedroom, beach umbrella
- Sensors and actuators used: Humidity, light, temperature, pressure
- Rules: temperature pressure , door status (open close), light status (high low medium off), phone status (busy, idle), water heater status (on off)

Bonsai [34]:

- Concepts: Noise, co2 level, room, air condition, light,
- Technologies used: zigbee, z-wave, W3C SSN ontology, DUL, protege editor tool

Kofler et al. [18] propose the ThinkHome ontology [29] , where they describe

- Energy: nonrenewable energy such as coal, nuclear, oil, natural gas and renewable energy like water wind, solar, wood…
- Energy providers: electric, gas, water, wood.
- Energy tariffs
- Energy facilities
- Energies properties

Their prototype propose a self-regulation of heating and cooling system tailored to schedule (nigh-time, weekends, holidays, seasons).

Wemlinger [36]

Codamos [28]

Chen, Finin, Joshi and Perich worked on the SOUPA (Standard Ontology for Ubiquitous and Pervasive Applications) ontology [7] [8] [10] to describe user profiles, beliefs, desires, etc. and the COBRA architecture [5] [6] [9] to build smart meeting rooms. COBRA (Context Broker Architecture) developed by Chen, Finin et al. is a centralized architecture for context-aware systems in smart environment based on semantic web languages. This architecture does not use SWE standards. They developed EasyMeeting, an intelligent meeting room based on the COBRA architecture. They define a policy language for users to control the sharing of their information and two ontologies SOUPA and COBRA-ONT. The ontology COBRA-ONT is for modeling context in an intelligent meeting room:

- Places (a physical location: longitude, latitude, and string name). They propose AtomicPlace (a room, an hallway, stairway, restroom, parking lot) and CompoundPlace (e.g., Campus or building are comprised of rooms)
- Agents are Person (name, homepage, email address) or SoftwareAgent.
- Agent’s Location can detect some inconsistencies (a person who are in the same time in

a parking lot and in a room).

- Agent's Activity represents for instance a meeting (A PresentationSchedule with the start time, the end time, the presentation title etc.)

The SOUPA Ontology is split into:

- SOUPA Core which attempt to define generic vocabularies that are universal for different pervasive computing applications.
- SOUPA Extension defines additional vocabularies for supporting specific types of applications.

The Soupa[2] ontology defined by Chen et al. is composed of 11 ontologies (assertion, association, conference, contact, event, news, person, photo, project, publication, research). The person ontology redefines similar concepts without be linked to the FOAF ontology (name, firstName, middleName, lastName) and propose additional concepts such as PhDStudent, Visitor, GuestSpeaker, Professor, Student, etc. and interesting properties such as biography, relatedPublications to obtain additional information about the person.

II. Health Ontologies

Lafti et al. [19] define the equipment sh ontologies[3] (measurements such `BloodPressure`, `Temp Body`) and the person sh ontology[4] describes the patient concept, his diseases, allergies, and the person concept including the relationships with the family. Unfortunately is not linked with well-known ontologies such as FOAF or relationships. Common concepts are `has Allergy, hasDisease, Allergy, ArterialHypertension, Diabetes, Person, Patient`. And the task ontologies with activities.

Ontoreachir[5] [22] defines 2039 concepts and 200 relations for the reanimation surgery domain. We link concepts related to `Disease` and blood measurements (`HypertensionArterielle`, `Hypoglycemie`).

Physicology[6] describes concepts related to blood (`Pressure, Glucose`).
Yao et al. [37] develop the hospital ontology/CIHO[7]. They describe several `Diseases, Patients (hasDisease).`

[2] http://ebiquity.umbc.edu/ontology/

[3] http://www.gdst.uqam.ca/Documents/Ontologies/HIT/Equipment_SH_Ontology.owl

[4] http://www.gdst.uqam.ca/Documents/Ontologies/HIT/Person_SH_Ontology.owl

[5] Search on google (filetype:owl Ontoreachir)

[6] Search on google (filetype:owl Physicology)

[7] http://www.personal.psu.edu/wxy119/hospital_ontology.owl

The registry ontology[8] defines interesting concepts related to Patient or `Person` (name, age, height, weight, sex, blood type) and numerous diagnostics. This ontology is not linked to the FOAF ontology whereas both ontologies describe a `Person` and have some properties in common (`hasName`).

Roose et al. [1]

Yao et al. [37] [38]

Hennessy [15]

Lukkien, brandt [4]

Paganelli [24] [25]

Tabaoda [35]

Jovic [16]

Zhao [39]

Chapter 6. Reference the domain knowledge

Once domain experts have designed and implemented their domain knowledge, they can share it through the Web. They can share the ontologies, datasets and rules.

III. Ontology catalogue

2. Linked Open Vocabularies (LOV)

The Linked Open Vocabularies is a catalogue, created by the semantic web community which references more than 412 well-designed ontologies according to the semantic web best practices as depicted in the Figure 26.

[8] http://ontology-for-registry-of-children-with-special-needs.googlecode.com/svn-history/r23/trunk/Registry3.4.4.owl

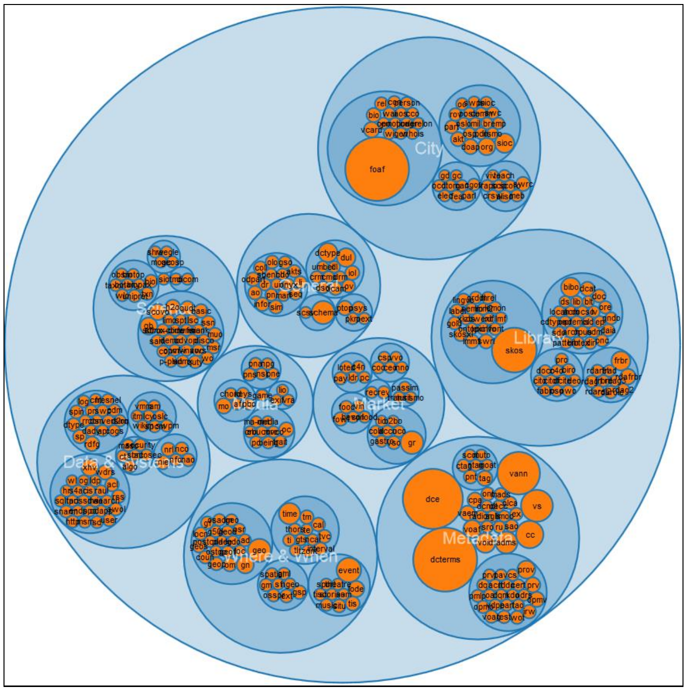


Figure 26. The Linked Open Vocabularies (LOV) catalogue

3. Linked Open Vocabularies for Internet of Things (LOV4IoT)

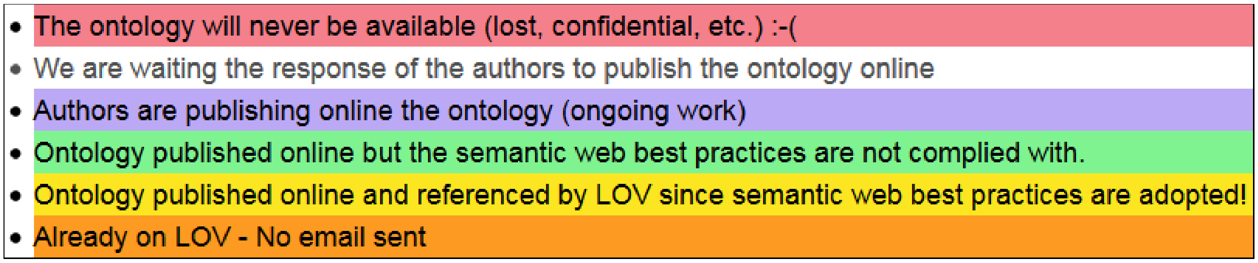
More than 170 **domain ontologies** have been designed by domain experts in various domains and cannot be referenced on the LOV catalogue since they do not respect the semantic web best practices. For this reason, these 170 domain ontologies have been referenced on this web site[9].

The ontologies are classified by:

- Domains such as building automation , healthcare, security, weather forecasting, intelligent transportation systems, affective science, tourism, agriculture, food, etc.
- Date
- Ontology status as displayed in the Figure 27:
    - Colored in white: Domain experts do not answer to emails
    - Colored in red: the ontology cannot be shared for diverse reasons (lost, confidential, etc.)
    - Colored in purple: domain experts intent to share and publish the ontology soon
    - Colored in green: the ontology is published online but not according to the semantic web best practices
    - Colored in yellow: the ontology is published online and the semantic web best practices are complied with

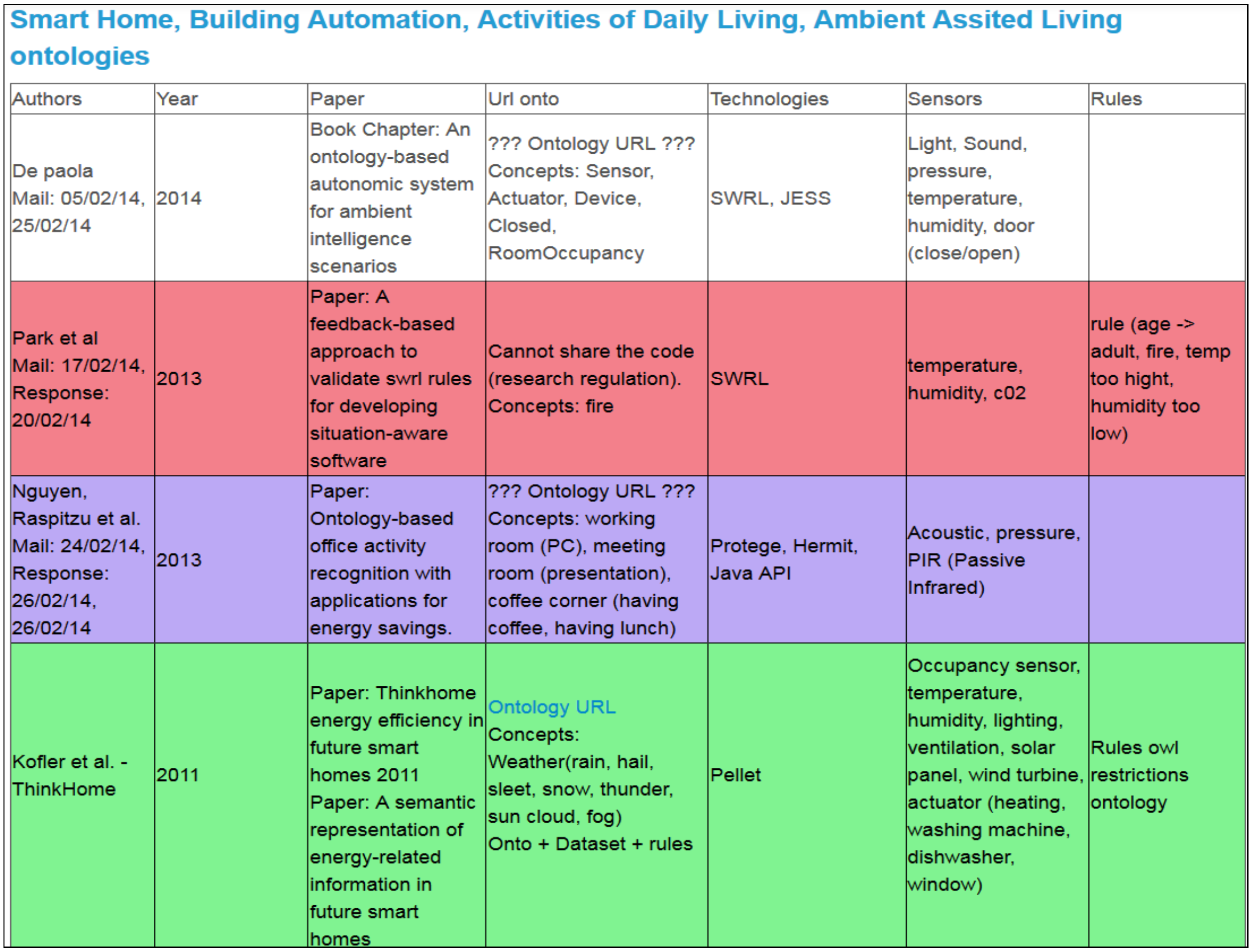
[9] http://www.sensormeasurement.appspot.com/?p=ontologies

- Colored in orange: few of them were already published online according to the semantic web best practices



- The ontology will never be available (lost, confidential, etc.) :-(
- We are waiting the response of the authors to publish the ontology online
- Authors are publishing online the ontology (ongoing work)
- Ontology published online but the semantic web best practices are not complied with.
- Ontology published online and referenced by LOV since semantic web best practices are adopted!
- Already on LOV - No email sent

Figure 27. Color code for the ontology status



Smart Home, Building Automation, Activities of Daily Living, Ambient Assited Living ontologies

Authors	Year	Paper	Url onto	Technologies	Sensors	Rules
De paola Mail: 05/02/14, 25/02/14	2014	Book Chapter: An ontology-based autonomic system for ambient intelligence scenarios	??? Ontology URL ??? Concepts: Sensor, Actuator, Device, Closed, RoomOccupancy	SWRL, JESS	Light, Sound, pressure, temperature, humidity, door (close/open)	
Park et al Mail: 17/02/14, Response: 20/02/14	2013	Paper: A feedback-based approach to validate swrl rules for developing situation-aware software	Cannot share the code (research regulation). Concepts: fire	SWRL	temperature, humidity, c02	rule (age -> adult, fire, temp too hight, humidity too low)
Nguyen, Raspitzu et al. Mail: 24/02/14, Response: 26/02/14, 26/02/14	2013	Paper: Ontology-based office activity recognition with applications for energy savings.	??? Ontology URL ??? Concepts: working room (PC), meeting room (presentation), coffee corner (having coffee, having lunch)	Protege, Hermit, Java API	Acoustic, pressure, PIR (Passive Infrared)	
Kofler et al. - ThinkHome	2011	Paper: Thinkhome energy efficiency in future smart homes 2011 Paper: A semantic representation of energy-related information in future smart homes	Ontology URL Concepts: Weather(rain, hail, sleet, snow, thunder, sun cloud, fog) Onto + Dataset + rules	Pellet	Occupancy sensor, temperature, humidity, lighting, ventilation, solar panel, wind turbine, actuator (heating, washing machine, dishwasher, window)	Rules owl restrictions ontology

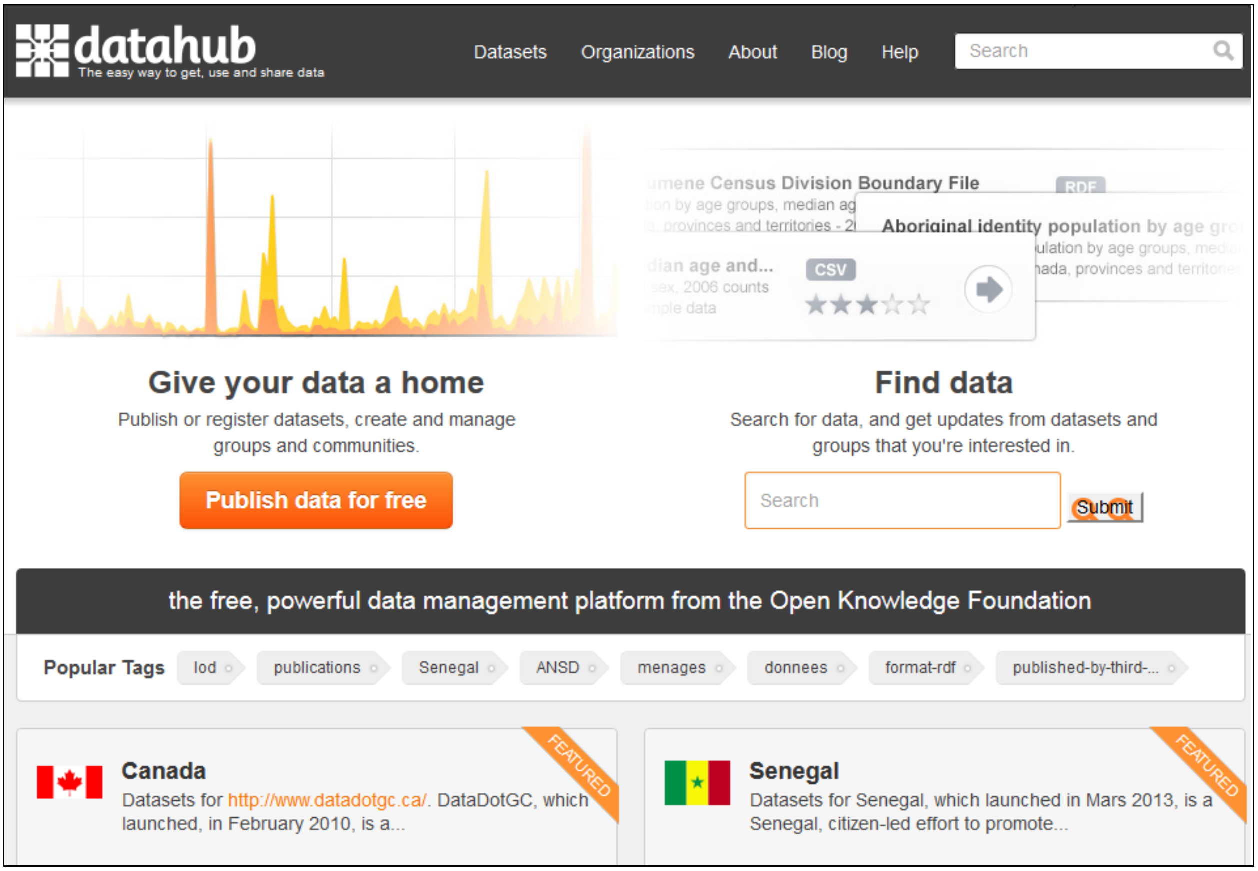
Figure 28. Ontology status in the building automation domain

Domain	Total onto	# No answer	# onto online	# onto lost	# ongoing onto	# ref by lov
Transport	26	11	6	4	5	0
Building Automation	28	10	6	3	8	1
Healthcare	34	11	12	6	5	0
Security	20	5	8	1	2	4
Tourism	26	10	10	4	1	1
Affective Science	5	1	2	0	0	2
Food, Beverage, Restaurant	22	9	9	0	3	1
Agriculture	7	5	1	1	0	0
Weather	9	2	5	0	0	2
Earthquake, pollution, environment	7	4	3	0	0	0

Figure 29. 178 ontology status classified by domain

IV. Dataset catalogue

- The DataHub project proposes an easy way to get, use and share data as depicted in the Figure 30.
- The Linked Open Data search engine as depicted in the Figure 31.



Give your data a home

Publish or register datasets, create and manage groups and communities.

Find data

Search for data, and get updates from datasets and groups that you're interested in.

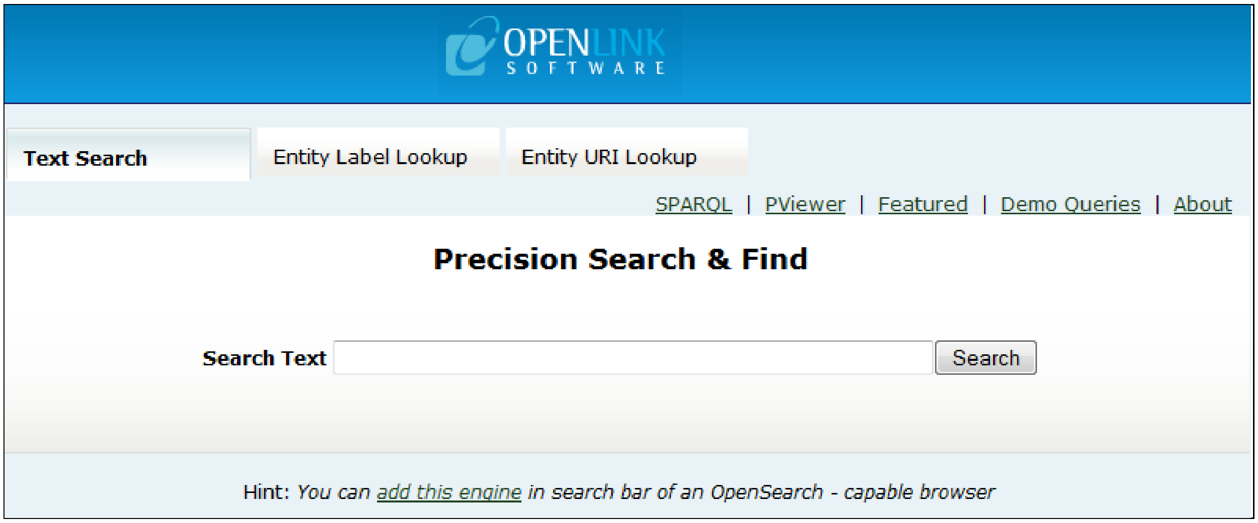
the free, powerful data management platform from the Open Knowledge Foundation

Popular Tags: lod, publications, Senegal, ANSD, menages, donnees, format-rdf, published-by-third-...

Canada
Datasets for http://www.datadotgc.ca/. DataDotGC, which launched, in February 2010, is a...

Senegal
Datasets for Senegal, which launched in Mars 2013, is a Senegal, citizen-led effort to promote...

Figure 30. DataHub



Precision Search & Find

Search Text

Hint: *You can add this engine in search bar of an OpenSearch - capable browser*

Figure 31. Linked Open Data search engine

V. Rules Catalogue

The “Linked Open Rules”, a work in progress, intents to share reuse and combine existing semantic web rules. See section Semantic tools

Chapter 7. Semantic web tools

I. Ontology editors, semantic API or framework

- Protégé is the most used ontology free editor tool to design a new ontology as depicted in the Figure 32 and proposes various plugin for ontology visualization, writting rules, etc.
- Callimachus
- TopBraid is a commercial solution to build semantic web and linked data applications
- SWOOP is a tool for creating, editing, and debugging OWL ontologies.
- Jena compatible with JAVA
- Virtuoso
- Sesame
- NeOn Toolkit
- OWL API as depicted in the Figure 33

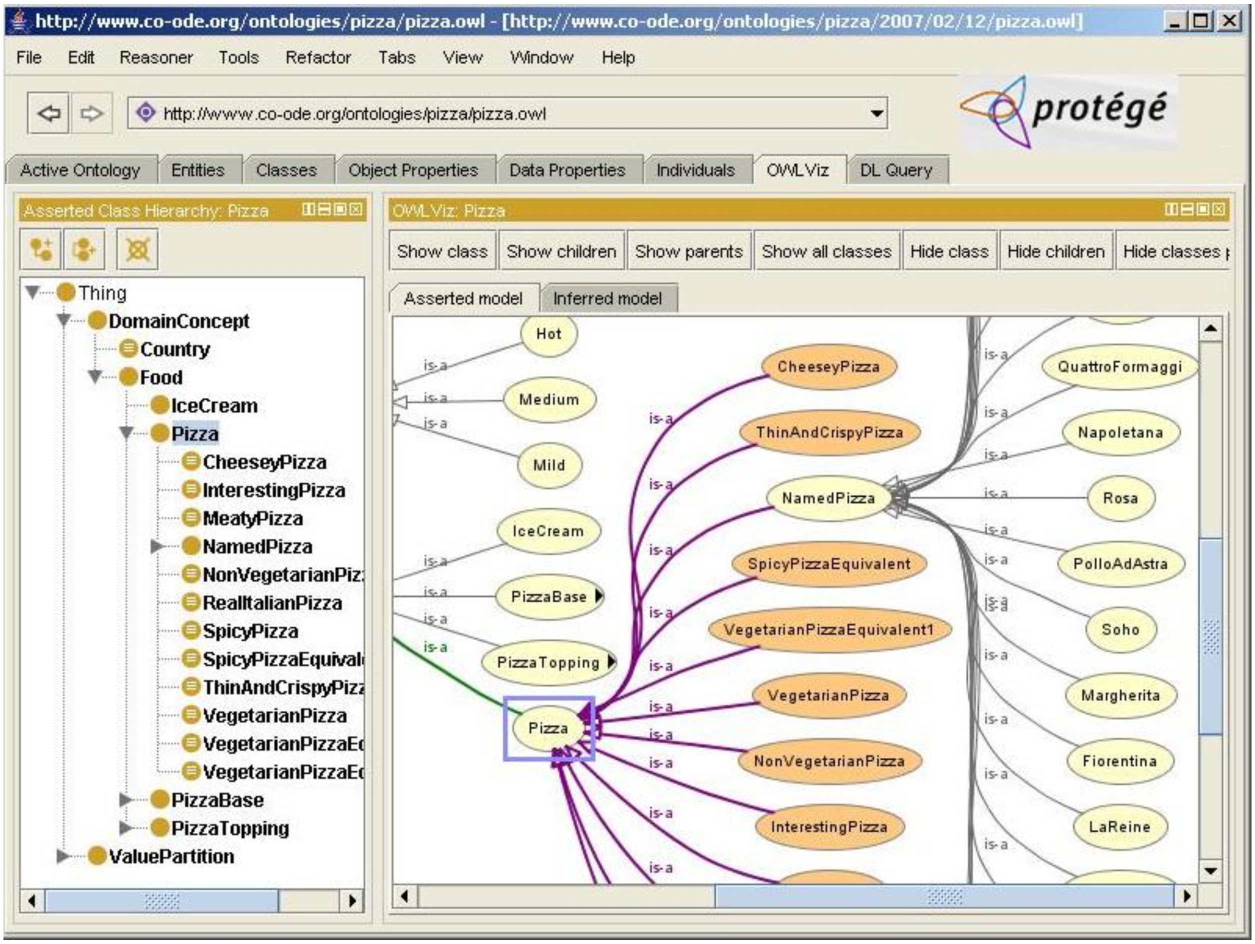
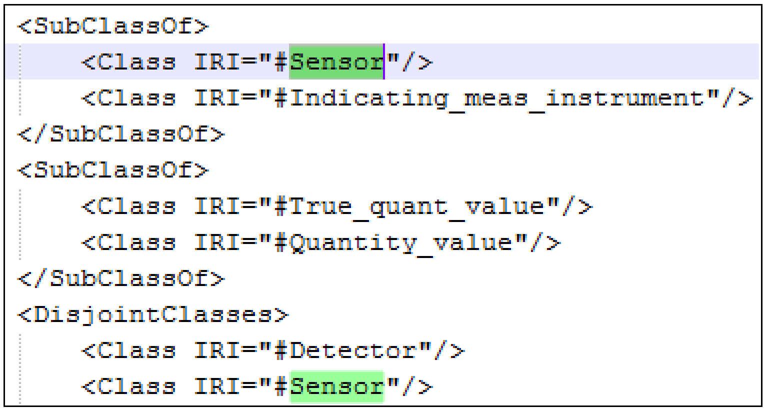


Figure 32. Protégé Editor tool



```
<SubClassOf>
    <Class IRI="#Sensor"/>
    <Class IRI="#Indicating_meas_instrument"/>
</SubClassOf>
<SubClassOf>
    <Class IRI="#True_quant_value"/>
    <Class IRI="#Quantity_value"/>
</SubClassOf>
<DisjointClasses>
    <Class IRI="#Detector"/>
    <Class IRI="#Sensor"/>
```

Figure 33. Ontology designed with OWL API [4]

II. Mapping tools

- LogMap is used to link ontologies with each other

- Silk is used to link datasets with each other
- SameAS is used to link datasets with each other
- LIMES (Linked Discovery Framework for Metric Spaces)
- RiMOM
- idMash
- ObjectCoref

III. Linked data search search engines

- Sindice provides API which can be used by Linked Data applications.
- Watson provides API which can be used by Linked Data applications.
- Swoogle provides API which can be used by Linked Data applications.
- OpenLink Data Explorer
- SchemaCache
- SchemaWeb
- Sig.ma
- Falcons
- SWSE

IV. Linked data browsers:

- Disco hyperdata browser
- Tabulator browser
- LinkSailor
- LOD Browser switch

V. Semantic Reasoner

- Jess
- Pellet is an OWL 2 reasoner for JAVA.
  - Pellet - Protege
  - Pellet - Jena
- Racer
- Kaon
- Fact++
- Hermit

VI. Converter

- Datalift
- SenML to RDF Converter

VII. Others

- Pubby
- Sindice Web data inspector: http://inspector.sindice.com/
- Purl
- Pachube
- URI validator: http://www.hyperthing.org/
- DSNotify informs consuming applications about changes.
- RDFa Distiller and Parser: http://www.w3.org/2007/08/pyRdfa/

Chapter 8. Serialisation

I. Turtle

Turtle is more readable by human.

II. N3

III. Rdf/xml

Rdf/xml is widely supported by tools that consume Linked Data.

Chapter 9. Reference

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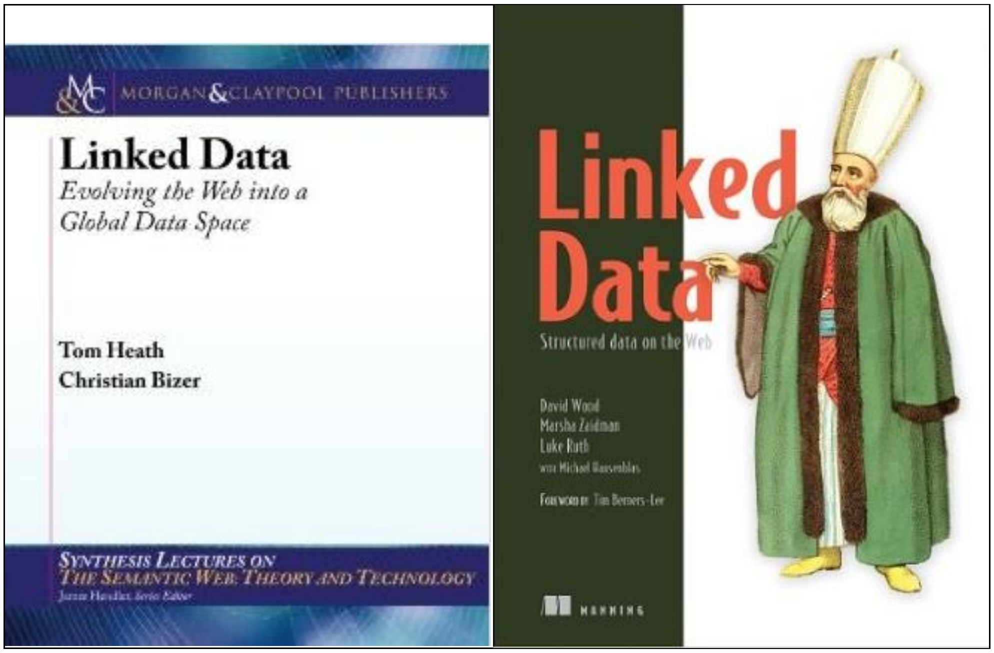
MORGAN&CLAYPOOL PUBLISHERS
Linked Data
Evolving the Web into a Global Data Space
Tom Heath
Christian Bizer
SYNTHESIS LECTURES ON THE SEMANTIC WEB: THEORY AND TECHNOLOGY
Linked Data
Structured data on the Web
David Wood
Marsha Zaidman
Luke Ruth
with Michael Hausenblas
FOREWORD BY Tim Berners-Lee
MANNING

Figure 34. Linked Data books

III. Annexe A: Ontology LOV metadata

Example:

```
        <owl:Ontology
rdf:about="http://securitytoolbox.appspot.com/securityAlgorithms#">
                <rdfs:comment> An ontology to describe various cryptographic
algorithms</rdfs:comment>
                <rdf:type
rdf:resource="http://purl.org/vocommons/voaf#Vocabulary"/>
                <dc:title xml:lang="en">Security Algorithms</dc:title>
                <skos:historyNote xml:lang="en">Ontology extracted from the
paper Security Ontology for Annotating Resources. [Kim et al. 2005] (See
APPENDIX D. OWL Representations of the NRL Security Ontology) Security
ontology to faciliate web service description and
discovery.</skos:historyNote>
                <dc:description xml:lang="en">An ontology to describe various
cryptographic algorithms</dc:description>
                <dcterms:source rdf:resource="http://www.dtic.mil/cgi-
bin/GetTRDoc?AD=ADA437938"/>
                <dcterms:creator>
                        <foaf:Person rdf:about="mailto:kim@itd.nrl.navy.mil">
                        <foaf:name>Anya Kim</foaf:name>
                        </foaf:Person>
                </dcterms:creator>
                <dcterms:issued
rdf:datatype="http://www.w3.org/2001/XMLSchema#date">2005-08-
31</dcterms:issued>
                <dcterms:modified
rdf:datatype="http://www.w3.org/2001/XMLSchema#date">2014-01-
24</dcterms:modified>
                <owl:versionInfo
rdf:datatype="http://www.w3.org/2001/XMLSchema#decimal">0.2</owl:versionInfo>
                <vs:term_status>Finished</vs:term_status>
        <cc:license
rdf:resource="http://creativecommons.org/licenses/by/3.0/"/>

        <vann:preferredNamespacePrefix>algo</vann:preferredNamespacePrefix>

<vann:preferredNamespaceUri>http://securitytoolbox.appspot.com/securityAlgori
thms#</vann:preferredNamespaceUri>
        </owl:Ontology>
```