Linked Open Vocabularies for Internet of Things (LOV4IoT)

Creator	Amelie Gyrard (Eurecom - Insight - NUIG/DERI) Designed and implemented by Amélie Gyrard, she was a PhD student at Eurecom under the supervision of Prof. Christian Bonnet and Dr. Karima Boudaoud. Currently, LOVIoT is maintained since she is a post-doc researcher at Insight within the IoT unit led by Dr. Martin Serrano.
Contributors	Nicolas Seydoux Ghislain Atemezing Thanks to the wonderful LOV team for sharing their expertise ☺
Send Feedback	Do not hesitate to ask for help or give us feedback, advices to improve our tools or documentations, fix bugs and make them more user-friendly and convenient: amelie.gyrard@insight-centre.org
Created	February 25, 2016
Last updated	February 26, 2016
Status	Work in progress
Goal	This documentation enables understanding the LOV4IoT tool: • Use the Graphical User interface (GUI) • Use the web services • Contribute to the LOV4IoT knowledge base Linked Open Vocabularies for Internet of Things (LOV4IoT) is an extension of Linked Open Vocabularies (LOV) for Internet of Things

Table of contents

Table of figures

Terms and acronyms

IoT	Internet of Things (IoT)
LOV	Linked Open Vocabularies

LOV4IoT	Linked Open Vocabularies for Internet of Things

I. Introduction: From LOV to LOV4IoT

Linked Open Vocabularies (LOV) [5] is an ontology catalogue designed by semantic web experts.

New ontologies should follow some best practices to be referenced. In Internet of Things, we classified almost 300 ontologies that cannot be referenced on LOV because of the “bad practices”.

For those reasons, we designed Linked Open Vocabularies for Internet of Things (LOV4IoT).

Figure 1. Linked Open Vocabularies (LOV)

1. Suggesting a vocabulary to LOV

Does your ontology contain ontology metadata as recommended by LOV? [6]

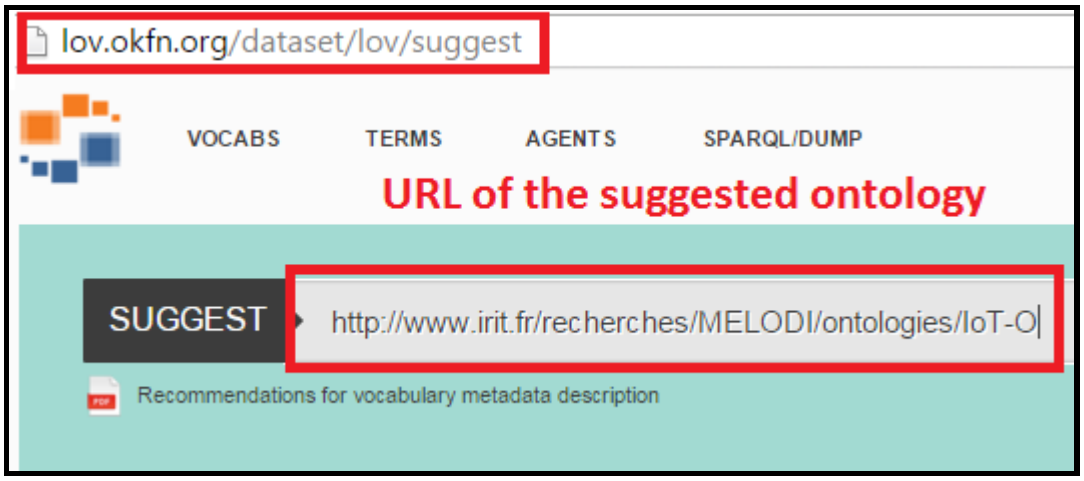

Figure 2. Suggest your ontology on LOV

II. Reusing domain knowledge with LOV4IoT

➔ Go to the Linked Open Vocabularies for Internet of Things (LOV4IoT) web page (see Figure 5): http://www.sensormeasurement.appspot.com/?p=ontologies

➔ Choose 1 domain by clicking on the image (e.g., transportation) as depicted in Figure 5.

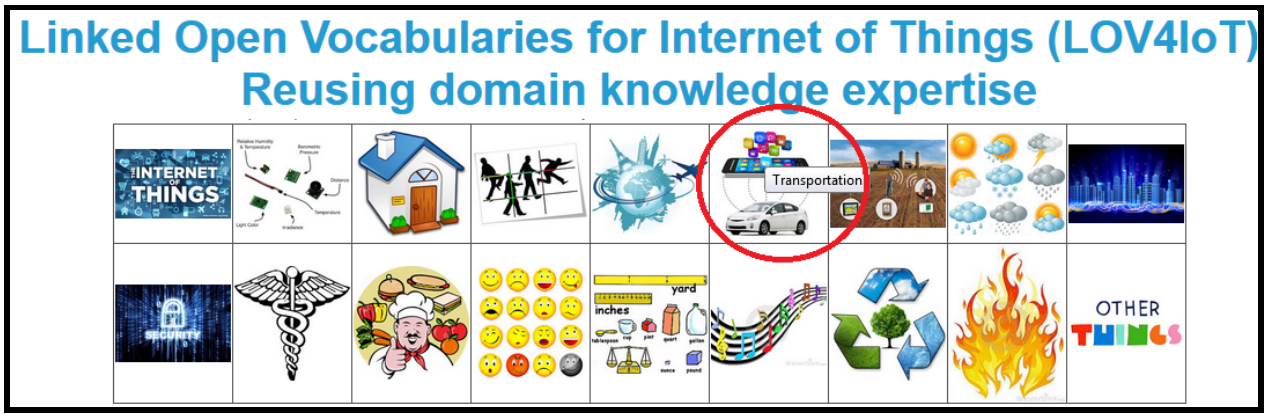

Figure 3. Ontologies classified in various domains

➔ You will find a table with the following information as depicted in Figure 7:

- Domain experts names (authors)
- Year of publication
- Research articles
- Ontology URL of available
- Technologies used in their project
- Sensors used in their project
- Rules designed

-Ontologies and projects have been classified according to different colors (see Figure 6):

- Red: the ontology is not available
- White: we do not have any links to get the ontology

- Orange: we contacted authors to get their ontologies. They answered us they will share ontologies and rules soon.
- Yellow: we retrieve the ontology URL or get a copy
- Green: Ontologies published online, cannot be referenced on the Linked Open Vocabularies (LOV)[1] project due to a lack of best practices.
- Dark green: The ontology is referenced on the Linked Open Vocabularies project. It checks 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 4. Classification of projects according to the reusability

Intelligent Transport Systems

Authors	Year	Paper	Url onto	Technologies	Sensors	Rules	LOV status	Security
Bermejo, Astrain Escola Mail: 14/02/14, Response: 18/02/14	2014	Paper: Ontology based road traffic management	No server (response), but sent us the OWL ontology copy URL Application ? Concepts: 24 classes, 12 properties, 77 rules. Vehicle	SWRL (DLSafeRule), Jess reasoner, extension of A3ME ontology, OWL API 3.4.2	LastBeforeGap, FirstAfterGap, NotOvertaker, Overtaker), distance sensor -> Space (Lateral, Ahead, Behind, NoSpace), Acceleration sensor (BigSpeedDifference, SpeedWith,	77 rules/actions (swrl dlsafe rule in the ontology) change line, decelerate, accelerate, maintain distance with car in front, maintain speed	Priority 1, responsive, ongoing, lov metadata, uri deferencable 26/03/14, ask for label and comment	
Morignot, Pollard et al.	2013	Paper: An ontology-based Model to determine the automation level of an automated vehicle for co-driving Paper: An ontology-based approach to relax traffic regulation for autonomous vehicle assistance	Ontology URL Ontology URL Concepts: emotion driver, Weather Conditions (foggy, cloudy, snowy, sunny, rainy), lighting conditions (day, night, setting sun), road (highway, campaing, urban, mountain), obstacles	Pellet, SWRL (DLSafeRule), Protege, SWOOPS (ontology editor)	Position, velocity, acceleration/braking and steering actuators	foggy -> mode manual, search for parking place, stopped, hasNextMotion	content negociation, uri def error, vapour rdf/xml	

Figure 5. Screenshot of LOV4IoT

III. LOV4IoT web services

1. LOV4IoTWS Java class

This Java class contains all web services related to LOV4IoT.

[1] http://lov.okfn.org/dataset/lov/

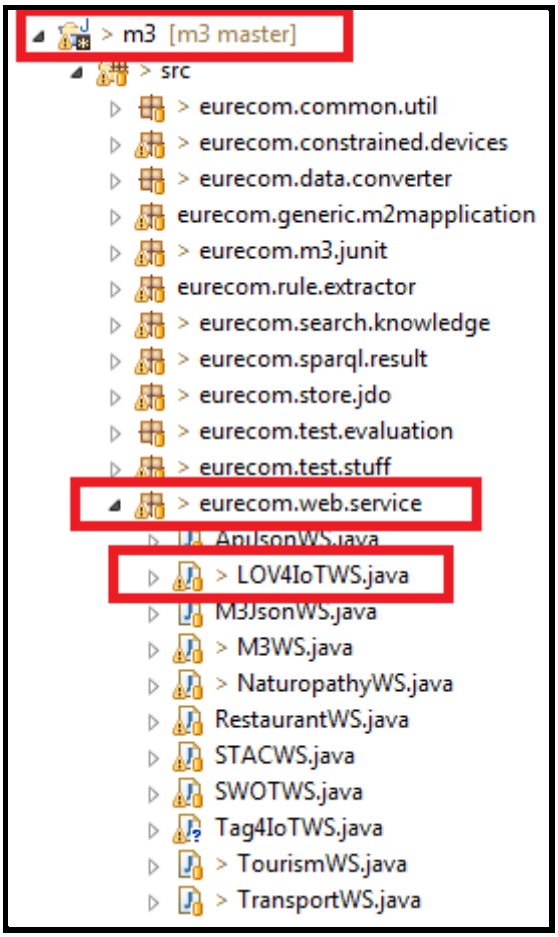

Figure 6. LOV4IoTWS Java Class location

2. LOV4IoTWS Explanations

All web services related to the Linked Open Vocabularies for Internet of Things (LOV4IoT) dataset[2] to automatically count the number of ontologies in this dataset (e.g., by domains, by ontology status, etc.):

- lov4iot/totalOnto/ which executes a SPARQL query to count the total number of ontology-based project referenced in the LOV4IoT RDF dataset.
  E.g., http://sensormeasurement.appspot.com/lov4iot/totalOnto/
- /lov4iot/ontoStatus/{status} which executes a SPARQL query to count the different status of ontologies
  - Status can be: Online, Confidential, OngoingProcessOnline, WaitForAnswer, Online, OnlineLOV, AlreadyLOV

  E.g., http://sensormeasurement.appspot.com/lov4iot/ontoStatus/?status=Online

- /lov4iot/nbOntoDomain/{domain} which executes a SPARQL query to count the different ontologies in all domains

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

- Domain can be: BuildingAutomation, Weather, Emotion, Agriculture, Health, Tourism, Transportation, City, EnergyFOI, Environment, TrackingFood, Activity, Fire, TrackingCD, TrackingDVD, SensorNetworks, IoT, Security

E.g.,
http://sensormeasurement.appspot.com/lov4iot/nbOntoDomain/?domain=BuildingAutomation

- /lov4iot/sendEmail/{recipient,paper} which sends email to encourage people to share their domain knowledge (ontologies, datasets, and rules)

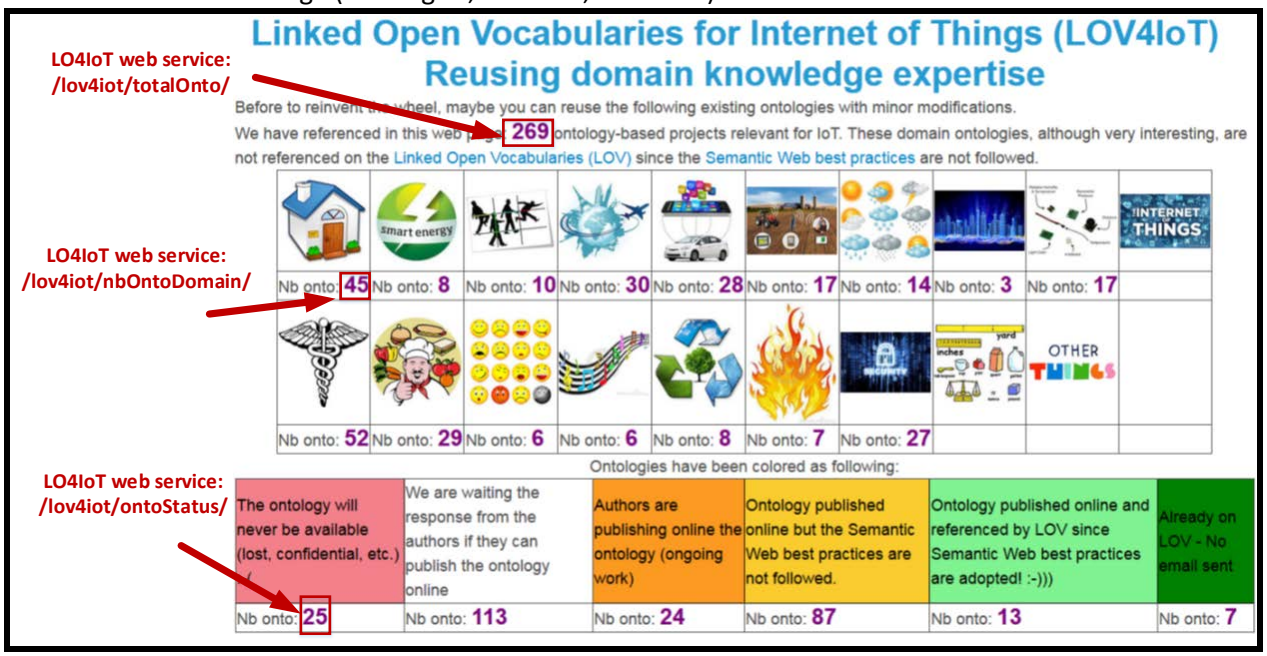

Figure 7. LOV4IoT web services

```
@GET
@Path("/totalOnto/")
@Produces(MediaType.APPLICATION_XML)
public Response getTotalNumberOntology() {
    //load the LOV4IoT dataset into the model
    Model model = ModelFactory.createDefaultModel();
    ReadFile.enrichJenaModelOntologyDataset(model, Var.LOV4IOT_DATASET_PATH);
    M2MAppGeneric m2mappli = new M2MAppGeneric(model);

    //SPARQL query
    ExecuteSparql sparqlQuery = new ExecuteSparql(model, Var.ROOT_SPARQL_LOV4IoT + "countTotalOntology.sparql");

    //no variable to replace in the SPARQL query
    ArrayList<VariableSparql> var = new ArrayList<VariableSparql>();
    String resultSparqlsenml = sparqlQuery.getSelectResultAsXML(var);

    return Response.status(200).entity(resultSparqlsenml).build();
}
```

Figure 8. Example of the lov4iot/totalOnto: web service

IV. LOV4IoT Bot

1. LOV Bot user interface

To encourage people to share their ontologies you can use the LOV4IoT bot[3].

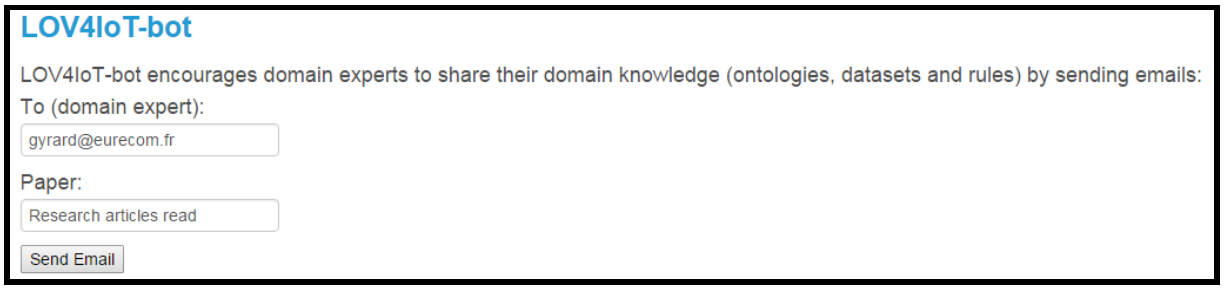

Figure 9. LOV4IoT bot user interface

2. LOV Bot explanations

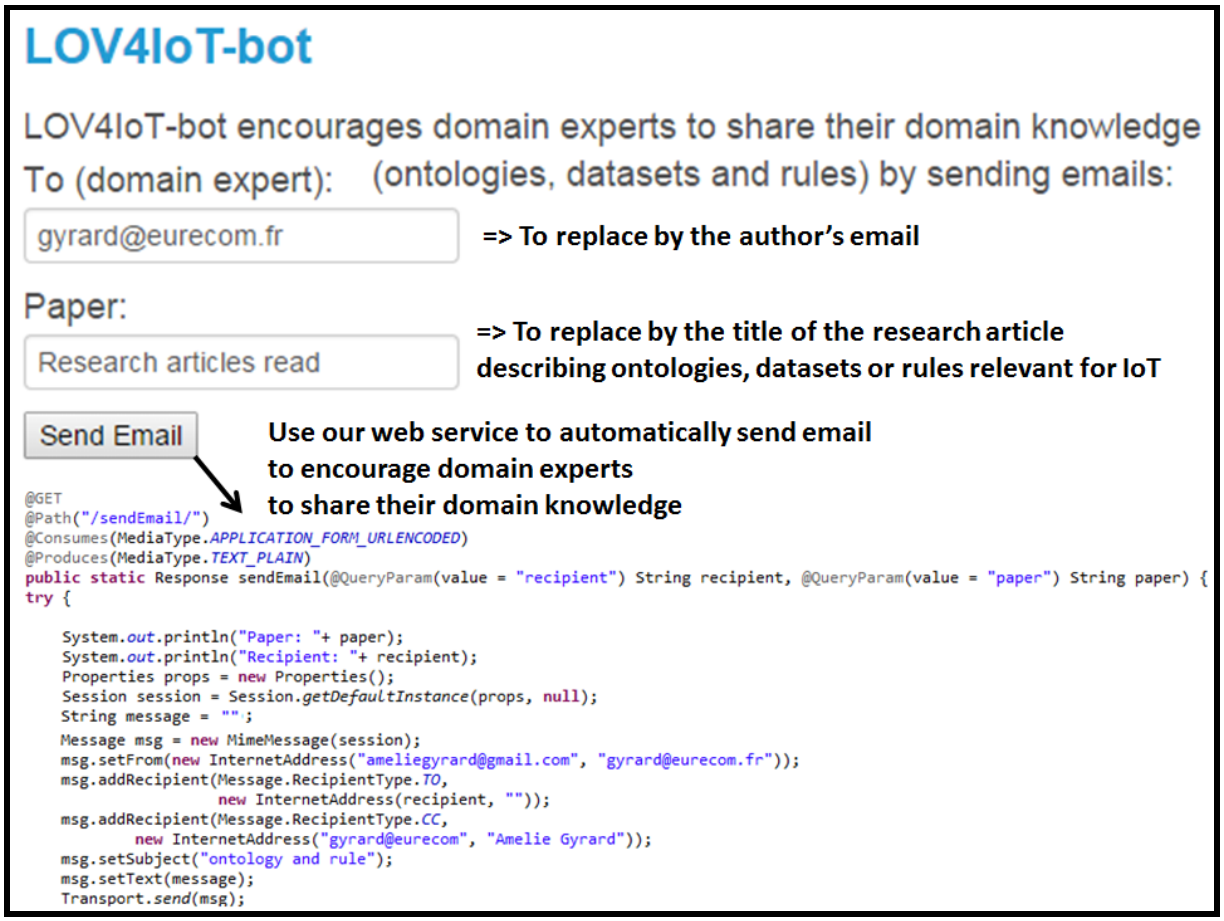

Figure 10. Code to send emails to convince authors to share their ontologies with LOV4IoT bot

[3] http://sensormeasurement.appspot.com/?p=lov4iot

V. Adding a new ontology in LOV4IoT

In the future, we will automatically build the HTML web page according to the LOV4IoT RDF dataset. This work is ongoing. Currently, we have to update the HTML web page and the RDF dataset when we want to reference a new onology-based project.

1. HTML web page

Go to m3/WAR/html/lov4iot.hml

Look for the table related to the domain, add a new line with all columns required.

http://sensormeasurement.appspot.com/?p=ontologies

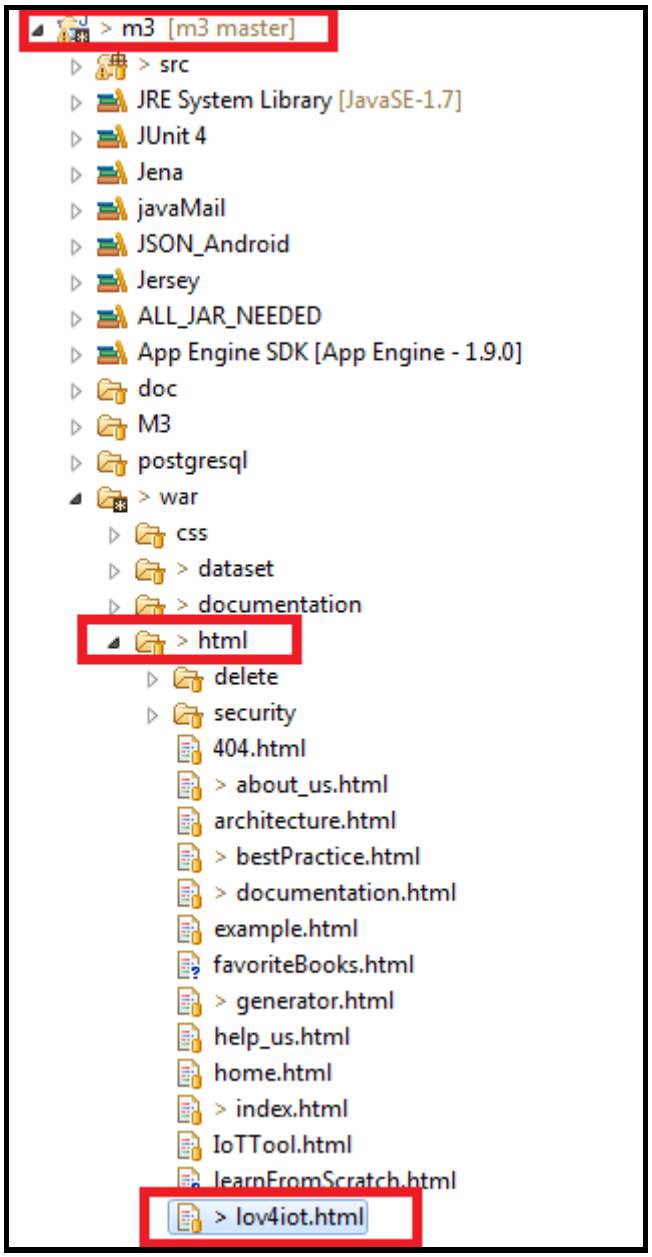

Figure 11. LOV4IoT HTML file location

2. LOV4IoT RDF dataset

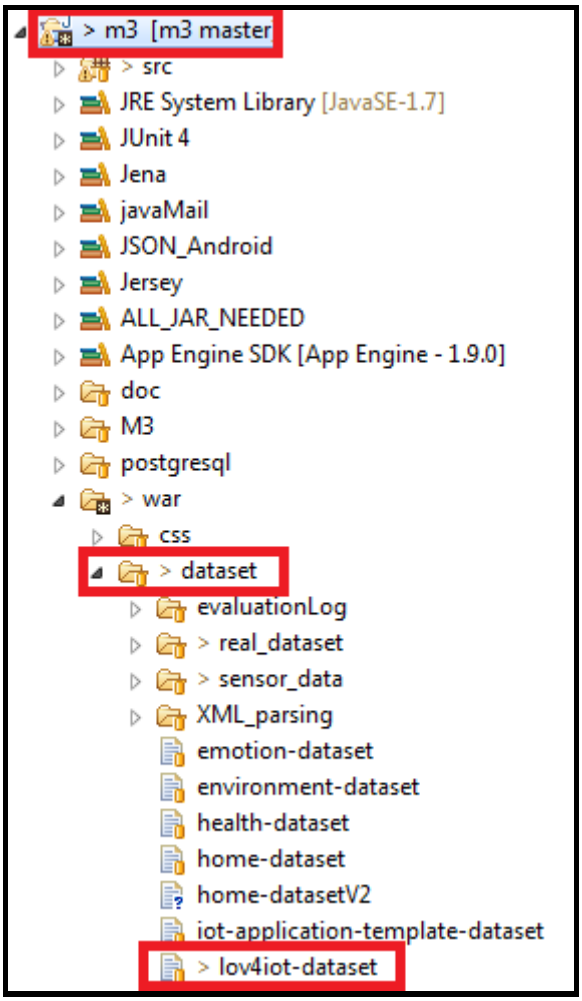

Figure 12. LOV4IoT HTML file location

In the LOV4IoT RDF dataset[4], add a new ontology-based project.

[4] http://www.sensormeasurement.appspot.com/dataset/lov4iot-dataset

```
<m3:M2MApplication rdf:about="PaulStaroch">
    <m3:hasContext rdf:resource="&m3;Weather"/>
    <m3:hasContext rdf:resource="&m3;BuildingAutomation"/>
    <rdfs:label xml:lang="en">[Paul Staroch 2013]. See LOV4IoT for more details.</rdfs:label>
    <rdfs:comment xml:lang="en">Master's Thesis: A weather ontology for predictive control
    <m3:hasM2MDevice rdf:resource="&m3;Thermometer"/>      in smart homes. 2013</rdfs:comment>
    <m3:hasM2MDevice rdf:resource="&m3;PrecipitationSensor"/>
    <m3:hasM2MDevice rdf:resource="&m3;HumiditySensor"/>
    <m3:hasM2MDevice rdf:resource="&m3;AtmosphericPressureSensor"/>
    <m3:hasM2MDevice rdf:resource="&m3;SolarRadiationSensor"/>
    <m3:hasM2MDevice rdf:resource="&m3;WindDirectionSensor"/>
    <m3:hasM2MDevice rdf:resource="&m3;WindSpeedSensor"/>
    <m3:hasM2MDevice rdf:resource="&m3;SunPositionDirectionSensor"/>
    <m3:hasM2MDevice rdf:resource="&m3;SunPositionElevationSensor"/>
    <m3:hasM2MDevice rdf:resource="&m3;CloudCoverSensor"/>
    <m3:hasUrlOntology rdf:resource="http://paul.staroch.name/thesis/SmartHomeWeather.owl"/>
    <m3:hasUrlRule rdf:resource="http://paul.staroch.name/thesis/SmartHomeWeather.owl"/>
    <lov4iot:hasOntologyStatus rdf:resource="&lov4iot;OnlineLOV"/>
    <dcterms:creator>
        <foaf:Person rdf:about="mailto:paul@staroch.name">
        <foaf:name>Paul Staroch</foaf:name>
        </foaf:Person>
    </dcterms:creator>
</m3:M2MApplication>
```

Figure 13. An ontology-based project referenced in the LOV4IoT RDF dataset

VI. LOV4IoT ontology

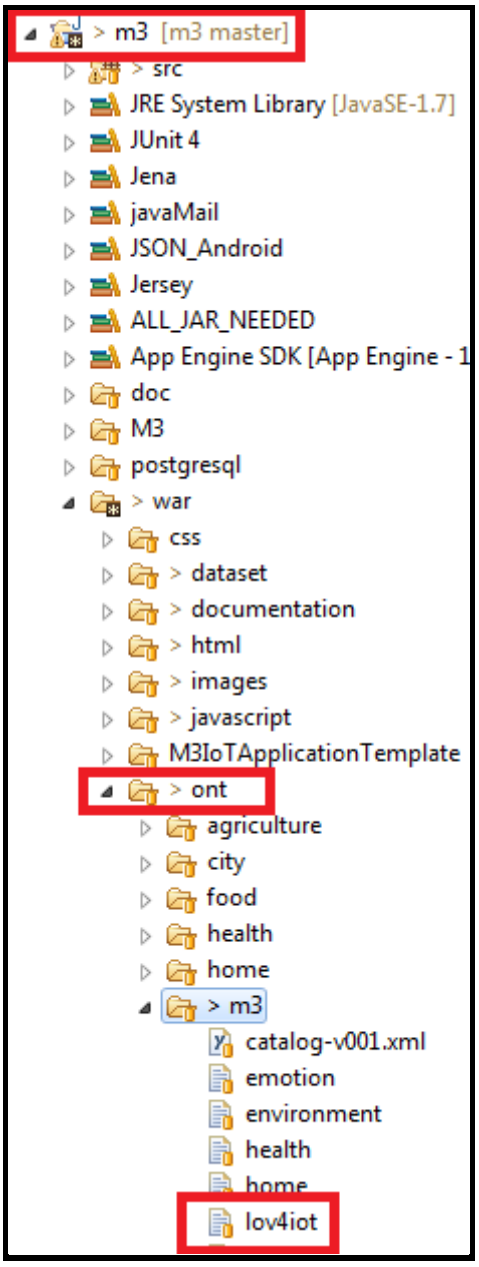

Figure 14. LOV4IoT ontology file location

3. Visualizing LOV4IoT with WEBVOWL

http://vowl.visualdataweb.org/webvowl/#iri=http://sensormeasurement.appspot.com/ont/m3/lov4iot#

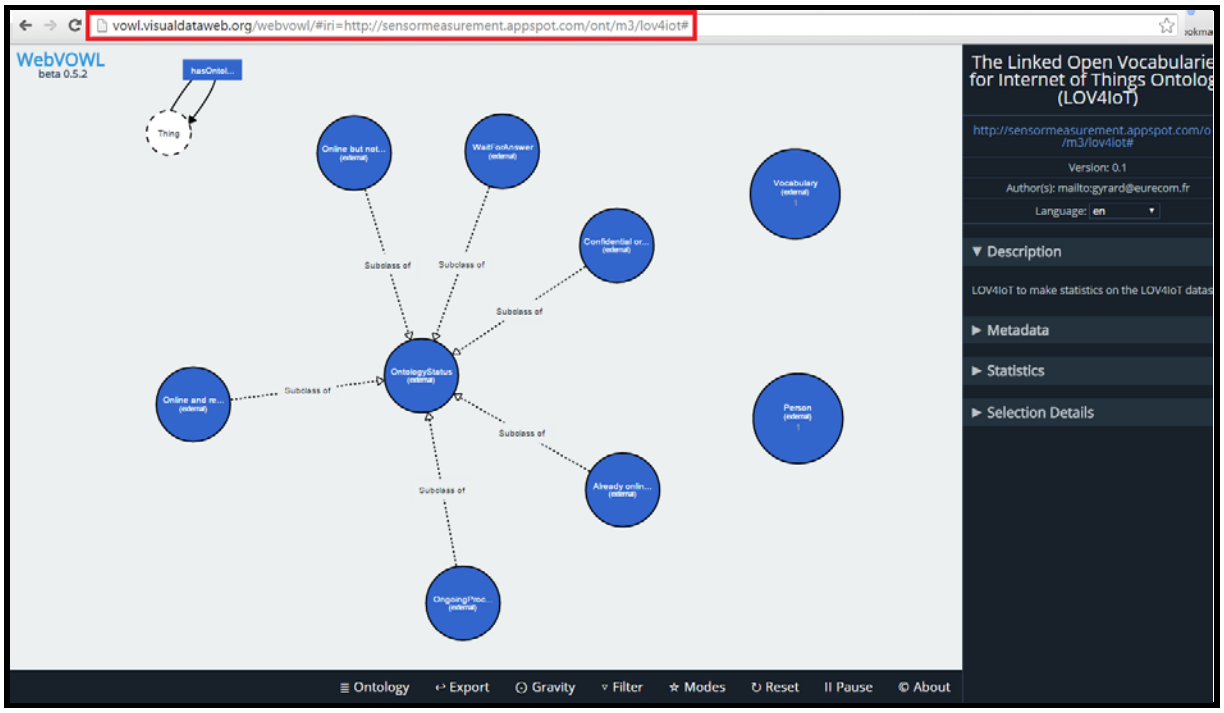

Figure 15. Visualizing LOV4IoT ontology with WEBVOWL

VII. LOV4IoT Architecture

TO DO: Take inspiration from LOV paper?

VIII. LOV4IoT sequence diagram

TO DO

IX. Repository purl with Ghis

X. Lessons Learnt: Best Practices

We have learnt a set of best practices. More explanations can be found in [4] [3].

Reminder List of tools:

- Vapour [1]
- See this web page[5] for more tools
- ProtegeLOV[6] [2]

[5] http://localhost:50101/?p=bestPractice

[6] http://data.semanticweb.org/conference/eswc/2015/paper/demo/2

- LOV ontology metadata [6]

XI. Improvements ideas

- Improve the user interface
- Automatically update the LOV4IoT database
- Creation of an automatic workflow to check the best practices
- Interconnecting LOV4IoT with LOV
- Encourage best practices with some tools (e.g., ProtegeLOV extension)

1. Improving the user interface

- TO DO: Take inspiration from LOV user interface[7] and adapt it to IoT domain:
- Technology used: D3.js javaScript library for visualizations.

[7] http://lov.okfn.org/dataset/lov/

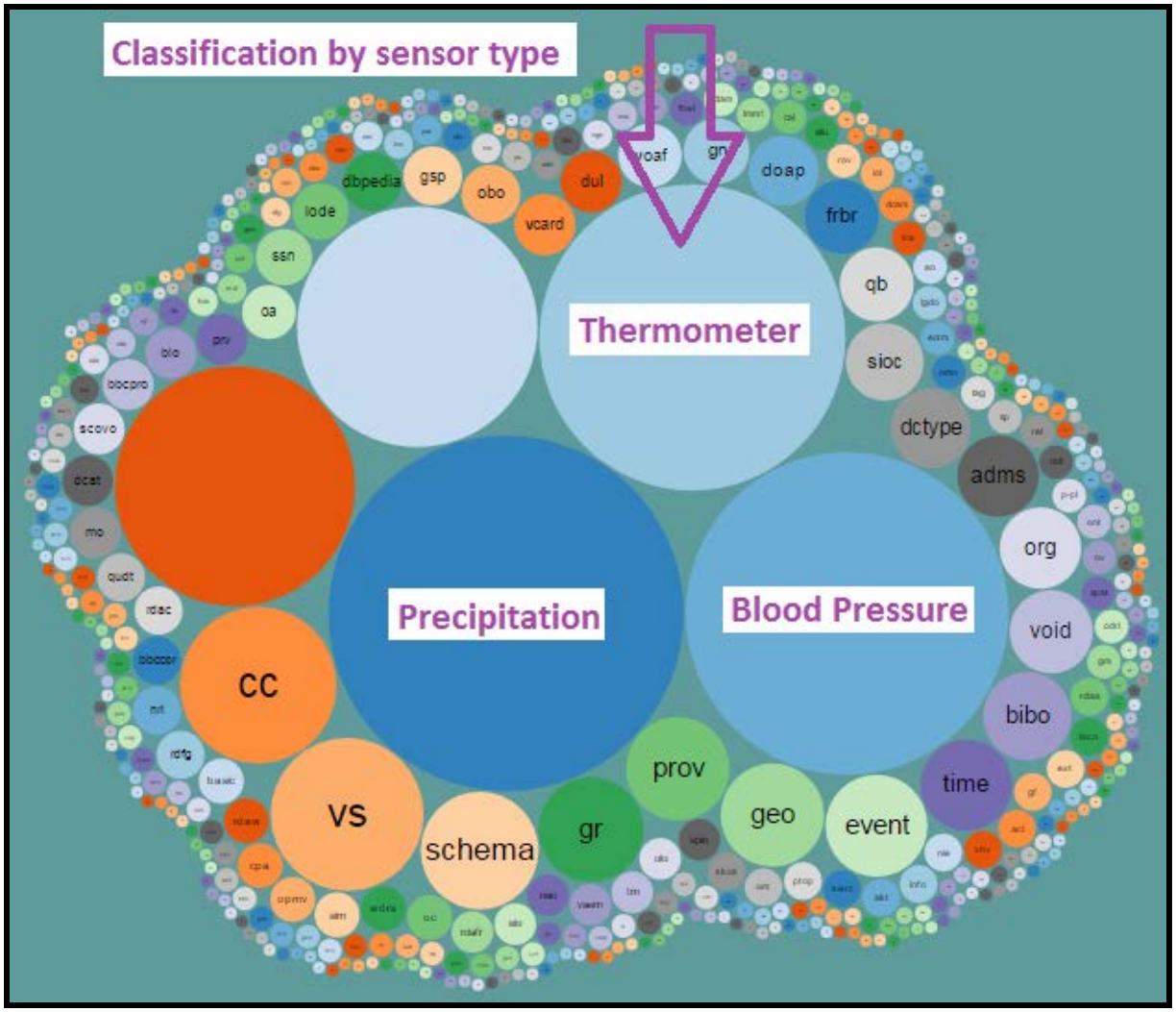

Figure 16. Bubble view to classify ontologies according to the sensor type

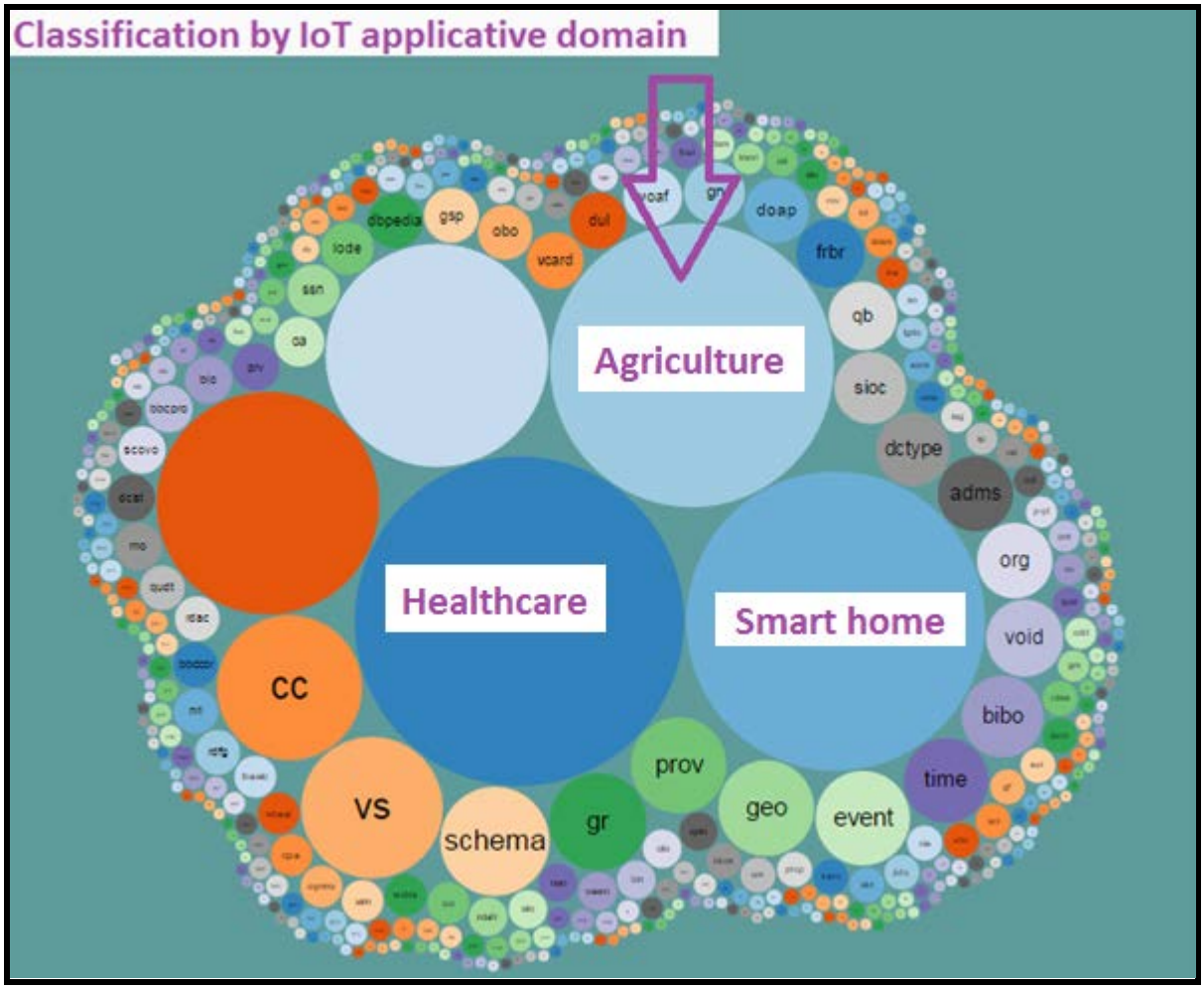

Figure 17. Bubble view to classify ontologies according to the IoT applicative domain

2. Checking best practices

LOV provides an interface for each ontology to use some tools such as:

- **WebVOWL** to visualize the ontology
- **Oops** to detect common ontology pitfalls
- **Parrot** to see the documentation of the ontology
- **Vapour** to check that the ONTOLOGY URL is deferencable (content negociation)
- RDF Triple-Checker to check some typos or syntax issues.

TO DO:

- Something similar with LOV4IoT
- Integration with more tools referenced in [4].
- Creating the entire workflow of validation.

Figure 18. Best practices tools integrated with LOV

XII. LOV4IoT Citations

Please do not forget to cite our LOV4IoT work:

- Semantic Web Methodologies, Best Practices and Ontology Engineering Applied to Internet of Things IEEE World Forum on Internet of Things (WF-IoT), Milan, Italy, December 14-16, 2015 Amelie Gyrard, Martin Serrano, Ghislain Atemezing
- Domain knowledge Interoperability to build the Semantic Web of Things W3C Web of Things, 25-26 June 2014, Berlin, Germany Amelie Gyrard, Christian Bonnet and Karima Boudaoud
- Semantic Web Guidelines for domain knowledge interoperability to build the Semantic Web of Things OneM2M International standard, Management, Abstraction and Semantics (MAS) Working Group 5, April 2014 Amelie Gyrard, Christian Bonnet

XIII. References

[1] Diego Berrueta, Sergio Fernández, and Iván Frade. Cooking http content negotiation with vapour. In *Proceedings of 4th Workshop on Scripting for the Semantic Web (SFSW2008)*. Citeseer, 2008.

[2] Nuria García-Santa, Ghislain Auguste Atemezing, and Boris Villazón-Terrazas. The protégélov plugin: Ontology access and reuse for everyone. In *The 12th Extented Semantic Web Conference (ESWC2015)*.

[3] Amélie Gyrard and Christian Bonnet. Semantic Web best practices: Semantic Web Guidelines for domain knowledge interoperability to build the Semantic Web of Things, 04 2014.

[4] Amelie Gyrard, Martin Serrano, and Ghislain Atemezing. Semantic web methodologies, best practices and ontology engineering applied to internet of things. In *WF-IOT 2015, World Forum on Internet of Things, 14-16 December 2015, Milan, Italy*, 2015.

[5] Pierre-Yves Vandenbussche, Ghislain A Atemezing, Mará Poveda-Villalón, and Bernard Vatant. Lov: a gateway to reusable semantic vocabularies on the web. *Semantic Web Journal*, 2015.

[6] Pierre-Yves Vandenbussche and Bernard Vatant. Metadata recommendations for linked open data vocabularies. *Version*, 1:2011–12, 2011.