
**UNIVERSITÀ DEGLI STUDI DI ROMA TOR VERGATA**

FACOLTÀ DI INGEGNERIA


# Artificial Intelligence

A.A. 2015/2016

**Exam Report**

Todo


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# Contents

**Abstract**

This paper is an academic final report for the Artificial Intelligence course. The goal of the project is to implement a Ros module for building high-level representations of the environment that embody both metric and symbolic knowledge about it. A key issue in the interaction with robots is to establish a proper relationship between the symbols used in the representation and the corresponding elements of the operational environment.

# 1 Introduction

Robotics is in an exciting stage and human machine interaction is being intensively studied. Robots are expected to get closely involved into human life as they are being marketed for commercial applications such as telepresence, service or entertainment. However, although they are expected to become consumer products, there is still a gap in terms of user expectations and robot functionalities. A key limiting factor is the lack of awareness of the robot on the operational environment. This project investigates several strategies to integrate a knowledge base in the ROS framework. The implemented system provides knowledge processing capabilities that combine knowledge representation and reasoning methods to manipulate and interact with physical objects of the operational milieu through an *API system* and a graphical interface.

ADD ROADMAP

## 1.1 Objectives

1. Integrate a knowledge base in ROS,
2. Create a node to Parse owl files in ROS environment,
3. Consistency check of ontology,
4. Reasoner invocation,

5. Make the ROS environment aware of object's instances,
6. Graphical representation of the objects in the scene,
7. Insert new instance of object in the scene and check for consistency,
8. Delete instance and check for consistency,
9. List instances,
10. Graphical Scene configuration from Gazebo and automatic Abox update
11. Export current Abox in owl or different formats.

## 1.2 Project Schedule

A public git repository is available at the following github page

| Week | General Task | Documentation | Implementation |
|---|---|---|---|
| 1 | • Perform a literature review on the previous HuRIC publications | • Knowledge representation and Reasoning [11]<br>• Huric papers [1],[2],[3],[4], [5] | |
| 2 | • Literature review of ROS compatible triple store<br>• ROS compatible simulation environments | • ROS Documentation [6], [7]<br>• ROS compatible simulation environments [8], [9] | • Set up ROS environment.<br>• Brainstorm Software Architecture |
| 3 | • Literature review of RDFlib based papers<br>• Test of Gazebo Simulator | • Full Training session on Gazebo Simulator [10]<br>• Python library RDFLib test | • Test Json Parser node<br>• Populate a scene from json files. |
| 4 | • Kinect pointcloud literature review<br>• Object recognition papers review | • PointCloudLibrary documentation [16]<br>• Python SciPy library classifier documentation | • Parse test KnowledgeBase owl file with RDFLib<br>• Clear scene script in Gazebo. |
| 5 | • Integrate classification algorithms<br>• Optimize python code and ROS environment. | • ROS + PCL integration<br>• RDF library deep inspection | • Analyze pointcloud from kinect<br>• Scene analysis, plane segmentation<br>• Object recognition, vote classifier |
| 6 | • Owl Reasoner integration<br>• Test RDFlib and Apache Jena | • RDF lib documentation<br>• Apache Jena Fuseki Documentation [15] | • Create init node<br>• Spawn models script<br>• Remove models script<br>• Apache Jena basic setup |

| Week | General Task | Documentation | Implementation |
|---|---|---|---|
| 7 | • Consistency check<br>• RosJava integration<br>• Jena Ontology Api | • RosJava guidelines [12]<br>• Apache Jena Ontology Api [13] | • Integrate RosJava in Ros.<br>• Follow Jena Ontology Api tutorial. Basic rdf manipulation |
| 8 | • Consistency check | • RosJava guidelines [12]<br>• Jena Reasoner Documentation [14] | • Implement consistency check with Jena.<br>• Integrate Jena libraries in ROS<br>• Reasoner invocation in ROS. |
| 9 | • Owl A-box extraction<br>• Specialize Reasoner on Tbox | • RDFlib export documentation<br>• Jena Reasoner documentation | • Implement A-box generator Jena<br>• Retrieve information about instances |
| 10 | • Get info about model in Gazebo<br>• Specialize Reasoner on Tbox | • Programming Robots with Ros [9]<br>• Gazebo Documentation [10] | • Subscribe to gazebo modelStates in ROSJava<br>• Call spawn model service from ROSJava |
| 11 | • SPARQL queries Add, Delete, Update, GET Instance<br>• Coordinator Node Definition<br>• Interface between Semantic Map and Gazebo Node | • Jena Ontology Api Documentation [13]<br>• Gazebo Documentation [10] | • Jena RDF graph manipulation<br>• Jena SPARQL Delete and Add queries<br>• Jena SPARQL GetInstance queries |

| Week | General Task | Documentation | Implementation |
|---|---|---|---|
| 12 | • Test Case validation<br>• Use Case validation<br>• Application Demo | | • Testing of real world scenario<br>• Bug fixing<br>• Extern Node definition |

# 2 The Ontology

It is expected that mobile robots undertake various tasks not only in the industrial fields such as manufacturing plants and construction sites, but also in the environment we live in.

## 2.1 Tbox

In this project a generic home domain model has been taken into account.

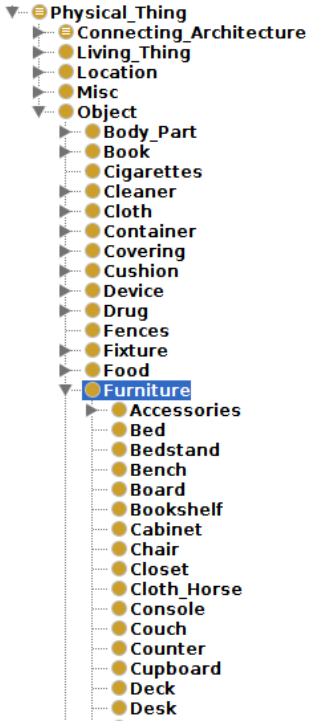


Figure 1: Physical Things

The furniture class describes several objects of a generic home environment a robot can interact with.

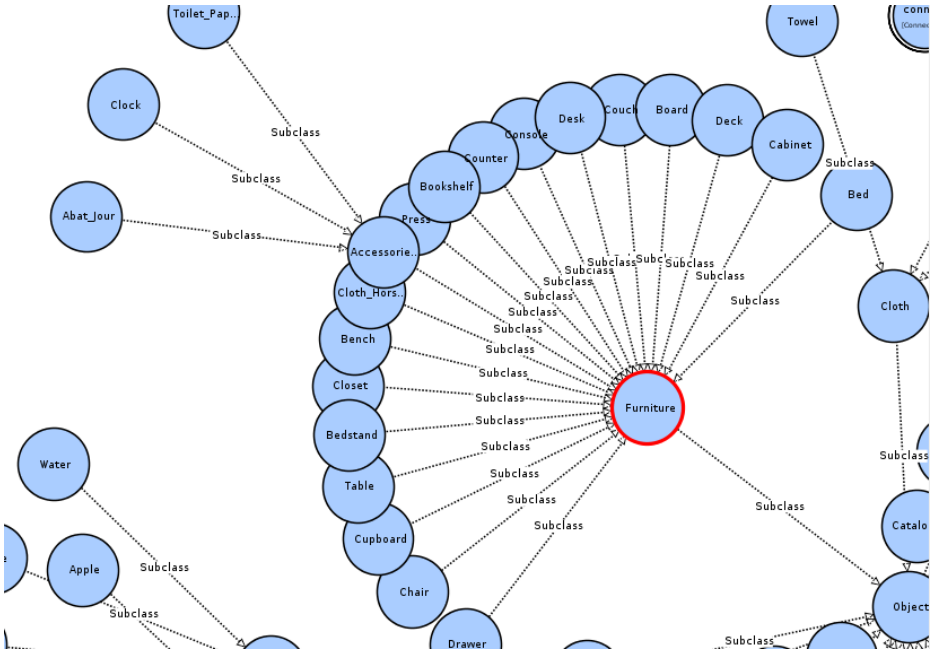


Figure 2: furniture subclasses

## Properties

OWL distinguishes between two main categories of properties that an ontology builder may want to define:

- Object properties link individuals to individuals.
- Datatype properties link individuals to data values.

An object property is defined as an instance of the built-in OWL class owl:ObjectProperty. A datatype property is defined as an instance of the built-in OWL class owl:DatatypeProperty. Both owl:ObjectProperty and owl:DatatypeProperty are subclasses of the RDF class rdf:Property.

### Properties

The datatypes involved are shown in the Figure 2.2 and 2.1

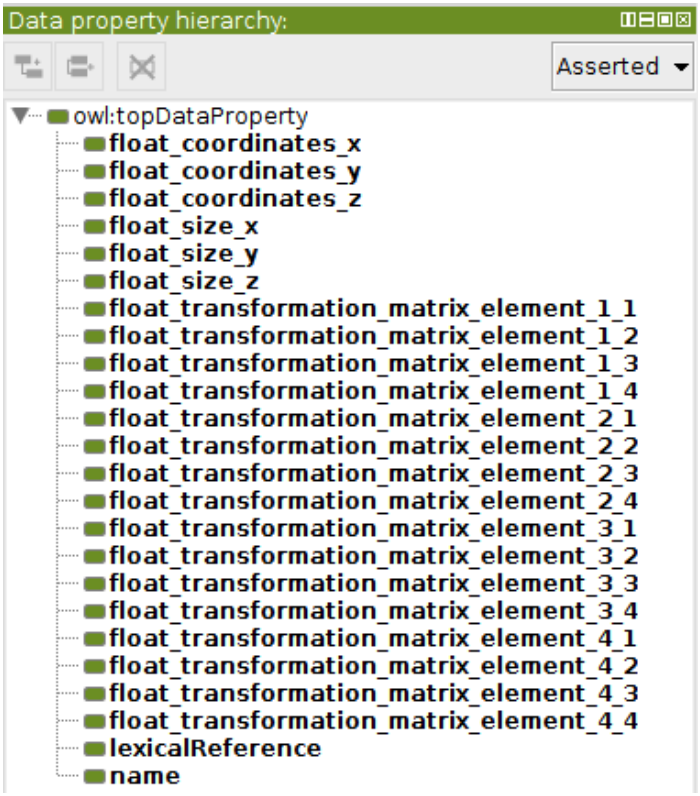


Figure 3: Datatypes Visual Protégé

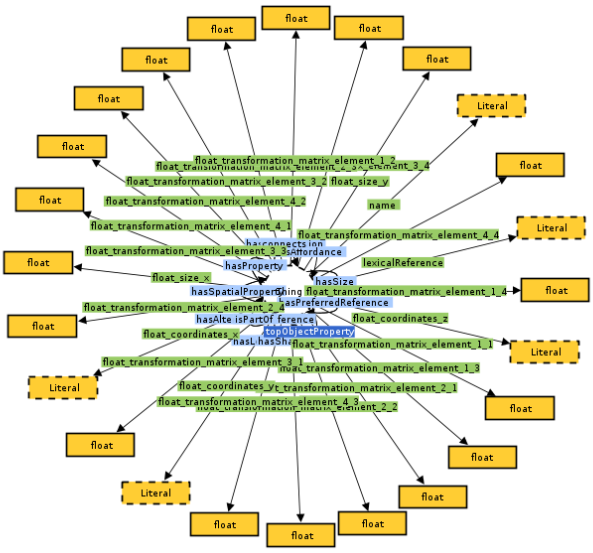


Figure 4: Datatypes

*Object Properties*

The following Figure 2.1 shows the class tree diagram of the ObjectProperties involved in the project.

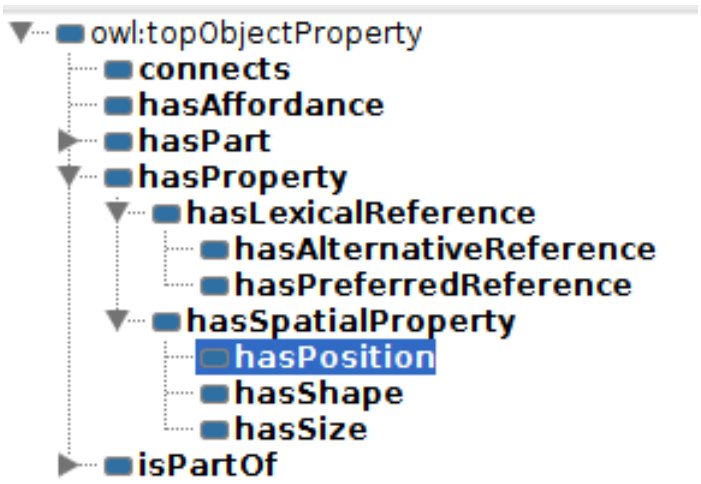


Figure 5: Object Properties Class Tree

As an example, consider the following set of owl statements about the ObjectProperty hasPosition. This property is of the type IrreflexivePropery and is a subProperty of Spacial-Property.

```
<owl:ObjectProperty rdf:about="sm#hasPosition">
    <rdfs:subPropertyOf rdf:resource="sm#hasSpatialProperty"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#IrreflexiveProperty"/>
</owl:ObjectProperty>
```

Let us consider another Property involved in this project.

```
<owl:Class rdf:about="sm#Coordinates">
    <rdfs:subClassOf rdf:resource="sm#Position"/>
    <rdfs:subClassOf>
       <owl:Restriction>
           <owl:onProperty rdf:resource="sm#float_coordinates_z"/>
           <owl:someValuesFrom ...
               rdf:resource="http://www.w3.org/2001/XMLSchema#float"/>
           </owl:Restriction>
     </rdfs:subClassOf>
     <rdfs:subClassOf>
        <owl:Restriction>
           <owl:onProperty rdf:resource="sm#float_coordinates_x"/>
           <owl:qualifiedCardinality ...
               rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1
           </owl:qualifiedCardinality>
           <owl:onDataRange ...
               rdf:resource="http://www.w3.org/2001/XMLSchema#float"/>
           </owl:Restriction>
     </rdfs:subClassOf>
     <rdfs:subClassOf>
        <owl:Restriction>
           <owl:onProperty rdf:resource="sm#float_coordinates_y"/>
```

```
20              <owl:qualifiedCardinality ...
                    rdf:datatype="http://www.w3.org/2001/XMLSchema#nonNegativeInteger">1
21               </owl:qualifiedCardinality>
22              <owl:onDataRange ...
                    rdf:resource="http://www.w3.org/2001/XMLSchema#float"/>
23          </owl:Restriction>
24      </rdfs:subClassOf>
25  </owl:Class>
```

The class Coordinates is a subclass of the class Position and of three anonymous classes. A property restriction describes an anonymous class, namely a class of all individuals that satisfy the restriction.
The first restriction is a Value contraint linked (using owl:onProperty) the Property float_coordinates_z to a class of all individuals for which at least one value of the property concerned is an instance of a data value in the data range.
The second and third restrictions are Cardinality contraints linked to the Property float_coordinates_x and float_coordinates_y.

## 2.2 Abox

The collection of individual are stored in a separate file called semantic_mapping, the Abox. The demo supports operations on four classes of instances since the 3D environment requires tridimentional models of the object to be represented. This constrain could be relaxed by adding an exhaustive collection of 3D models and by associating them to the corresponding classes.

### An instance of the class Chair

Individuals are defined with individual axioms called “facts”. These facts are statements indicating class membership of individuals and property values of individuals. As an example, consider the following set of statements about an instance of the class Chair:

```
1  <NamedIndividual rdf:about="sm#chair1">
2          <rdf:type rdf:resource="&semantic_mapping_domain_model;Chair"/>
3          <semantic_mapping_domain_model:hasPosition ...
               rdf:resource="sm#chair1_coordinates"/>
4          <semantic_mapping_domain_model:hasSize rdf:resource="sm#chair1_size"/>
5          <semantic_mapping_domain_model:hasAlternativeReference ...
               rdf:resource="sm#chair_alternative_reference_1"/>
6          <semantic_mapping_domain_model:hasAlternativeReference    ...
               rdf:resource="sm#chair_alternative_reference_2"/>
7          <semantic_mapping_domain_model:hasAlternativeReference  ...
               rdf:resource="sm#chair_alternative_reference_3"/>
8          <semantic_mapping_domain_model:hasPreferredReference ...
               rdf:resource="sm#chair_preferred_reference"/>
9      </NamedIndividual>
```

This example includes a number of facts about the individual chair1, an instance of the class Chair. The chair has three alternative references and one preferred lexical reference. These properties link a chair to a typed literal with the XML Schema datatype date. The XML schema document on datatypes contains the relevant information about syntax and

semantics of this datatype. The property hasPosition and hasSize link the chair to instances of the type Coordinates and Dimensions.

The following figure shows the same information on Protégé:

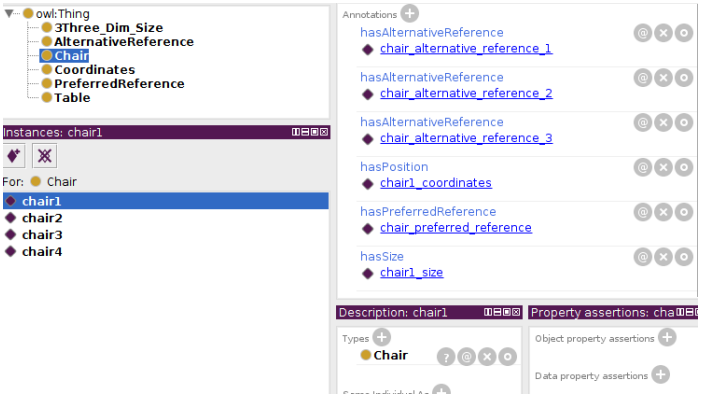


Figure 6: Chair1

**Properties**

The following example shows AlternativeReference instance property.

```
1  <NamedIndividual rdf:about="sm#chair_alternative_reference_1">
2          <rdf:type ...
               rdf:resource="&semantic_mapping_domain_model;AlternativeReference"/>
3          <semantic_mapping_domain_model:lexicalReference ...
               rdf:datatype="&xsd;string">chair
4          </semantic_mapping_domain_model:lexicalReference>
5      </NamedIndividual>
```

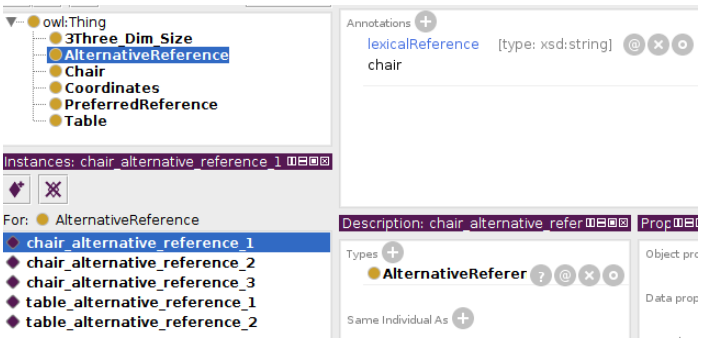


Figure 7: Alternative Reference 1

The following example shows the instance of the 3Three_Dim_Size property associated to the individual chair1

```
1  <NamedIndividual rdf:about="sm#chair1_coordinates">
2          <rdf:type rdf:resource="&semantic_mapping_domain_model;Coordinates"/>
```

```
3           <semantic_mapping_domain_model:float_coordinates_z ...
                rdf:datatype="&xsd;float">0.0
4           </semantic_mapping_domain_model:float_coordinates_z>
5           <semantic_mapping_domain_model:float_coordinates_y ...
                rdf:datatype="&xsd;float">0.0
6           </semantic_mapping_domain_model:float_coordinates_y>
7           <semantic_mapping_domain_model:float_coordinates_x ...
                rdf:datatype="&xsd;float">1.0
8           </semantic_mapping_domain_model:float_coordinates_x>
9       </NamedIndividual>
```

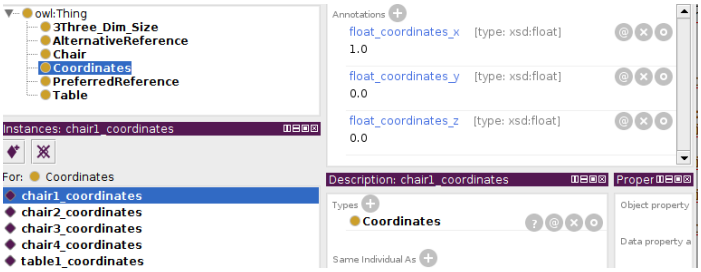


Figure 8: Coordinates chair 1

# 3 Involved Technologies

## 3.1 JENA Ontology API

The Jena ontology API is a Java programming toolkit. Jena's ontology support is limited to ontology formalisms built on top of RDF.

RDFS is the weakest ontology language supported by Jena. With RDFS it is possible to build a simple hierarchy of concepts, and a hierarchy of properties. There are various different ontology languages available for representing ontology information on the semantic web. They range from the most expressive, OWL Full, through to the weakest, RDFS.

The ontology language used in this project is the OWL FULL. OWL language allows properties to be denoted as transitive, symmetric or functional, and allows one property to be declared to be the inverse of another.

One of the key benefits of building an ontology-based application is using a reasoner to derive additional truths about the concepts you are modelling. Jena includes support for a variety of reasoners through the inference API.

A common feature of Jena reasoners is that they create a new RDF model which appears to contain the triples that are derived from reasoning as well as the triples that were asserted in the base model. The ontology API can query an extended inference model and extract information not explicitly given.

## 3.2 ROS Famework

The Robot Operating System (ROS) is a framework for writing robot software. It is a collection of tools, libraries and conventions that aims to simplify the task of creating complex and robust robot behavior across a wide variety of robotics platforms. The software is structured as a large number of modules that pass data to one another using a inter-process communication.

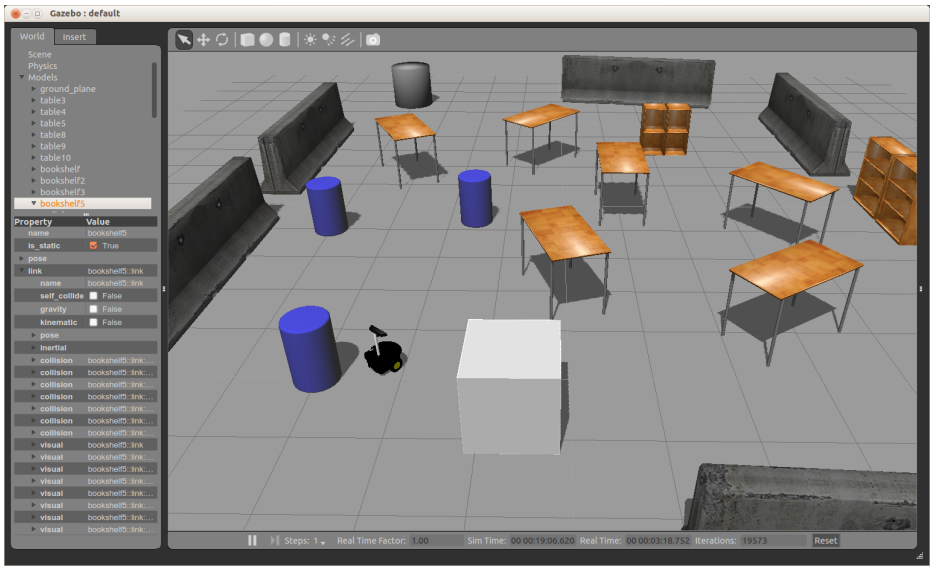


Figure 9: ROS simulation

ROS was built from the ground up to encourage collaborative robotics software development. A ROS system consists of numerous small computer programs that connect to one another and continuously exchange messages. There is no central routing service. It is a tools-based program. Tasks such as visualizing the system interconnections generating documentation, logging data, filtering sensor's data, etc. are all performed by separate programs. The individual tools themselves are relatively small and generic.
ROS chose a multilingual approach that allows programmers to accomplish tasks using scripting languages such as Python and MATLAB or using faster ones like C++. Client libraries exist for LISP, Java, JavaScript, Ruby,R and others. ROS libraries communicate with one another by following a convention that describes how messages are serialized before being transmitted over the network. The ROS conventions encourages contributors to create standalone libraries in order to allow the reuse of software and speed up development.

The core of ROS is released under the BSD license which allows commercial and noncommercial use.

## 3.3 Simulation Environment with Gazebo

Robotics implies robots. Most part of these platforms are used for research purposes and are custom built to investigate a particular aspect. However, there are a growing number of standard products that can be purchased and used out of the box for development and operations in many domains of robotics.

Although several robotics platforms are considered to be low cost they are still significant investments. Even the best robots can break periodically due to various combinations of operator error, environmental conditions, manufacturing and design defects.

All of these drawbacks can be avoided by using simulated robotic structures and a simulation environment. Gazebo is a $3D$ dynamic simulator with the ability to accurately and

efficiently simulate populations of robots in complex indoor and outdoor environments. It offers physics engine with high degree of fidelity and a variety of sensors.

Many robots are provided including *PR*2, *Pioneer*2 DX, iRobot Create, and TurtleBot. Thanks to URDF format, robotics platforms can be created from scratch and deployed into the simulator. With this environment it is possible to run simulation on remote servers, and interface to Gazebo through socket-based message.

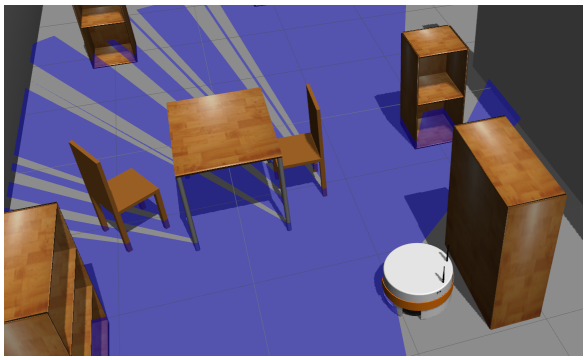

Figure 10: Gazebo Environment

Ros integrates closely with Gazebo through the *gazebo_ros* package. The latter provides a Gazebo plugin module that allows bidirectional communication between ROS and the simulator. Sensors, physics data, video input can stream from Gazebo to ROS and actuators commands can be forwarded to the simulation environment. By choosing consistent names and data types for these data streams it is possible to run the low level device-driver software on both the real robot and in the simulator.

# 4 The Architecture

This project has been implemented using ROS framework and it is a modular application that enables other nodes to query and interact with the knowledge base. Four nodes are involved in this application and the communication between them relies on an inter-process protocol handled by ROS.

## 4.1 System description

In the following subsection, the implememted nodes and their interaction with the system will be discussed.

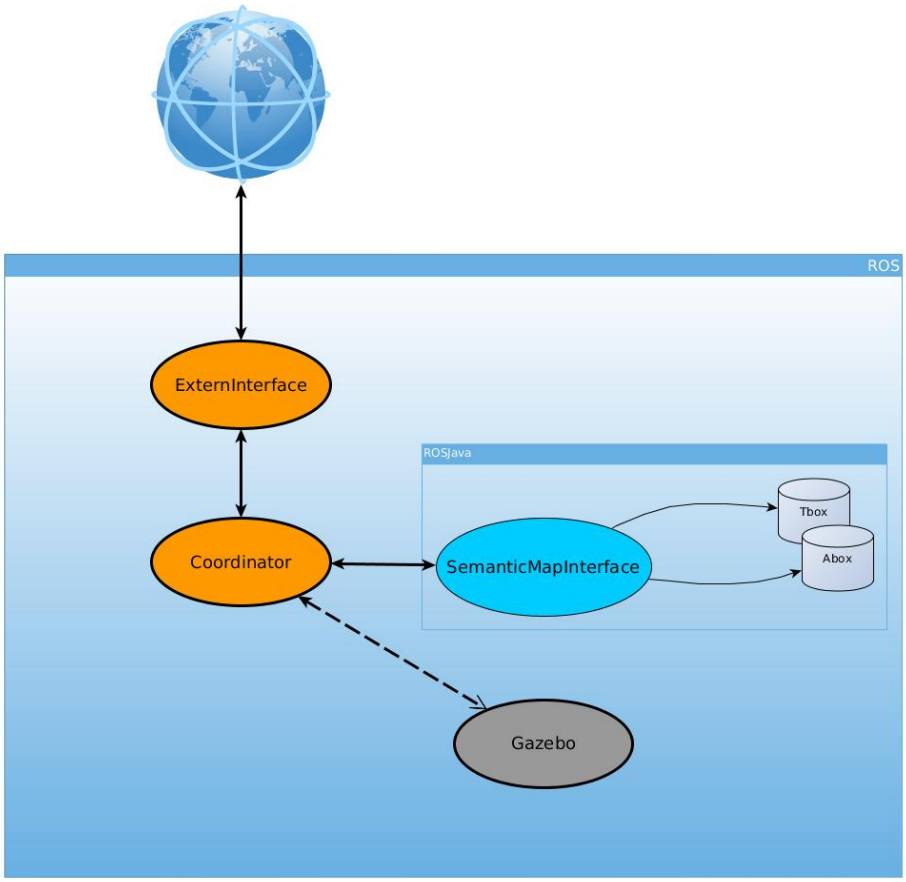


Figure 11: System Architecture

### 4.1.1 SemanticMapInterface Node

The knowledge base is loaded from the SemanticMapInterface which is a Java node based on the Jena Ontology API. This process allows requesting nodes to access and manipulate the ontology using a predefined set of operations.

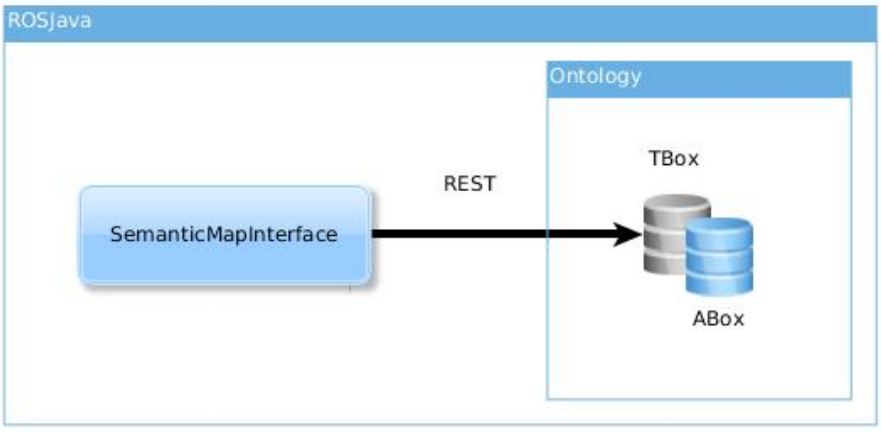


Figure 12: SemanticMapInterface Node

The exposed operations include:

- Loading the Terminology (TBox) and Assertion Box (ABox) into memory,
- Listing instances, their spacial properties and their preferred lexical reference,
- Adding a new entity of a particular class, with the spacial and lexical properties specified as arguments,
- Updating properties of active entities,
- Removing active entities,
- Invoking OWL-FULL reasoner and performing inference operation given a domain model,
- Exporting in OWL format the list of instances present or the augmented ABox with derived properties.

### 4.1.2 Coordinator Node

The main component is the Coordinator node. This python script performs several actions and communicates with other nodes in the system.

One responsability of the coordinator is to keep track of instances and trigger update requests when a 3D model is manually grabbed and moved in the simulation. This node provides a dynamic rooting of requests from the External Node to the ontology module or Gazebo.

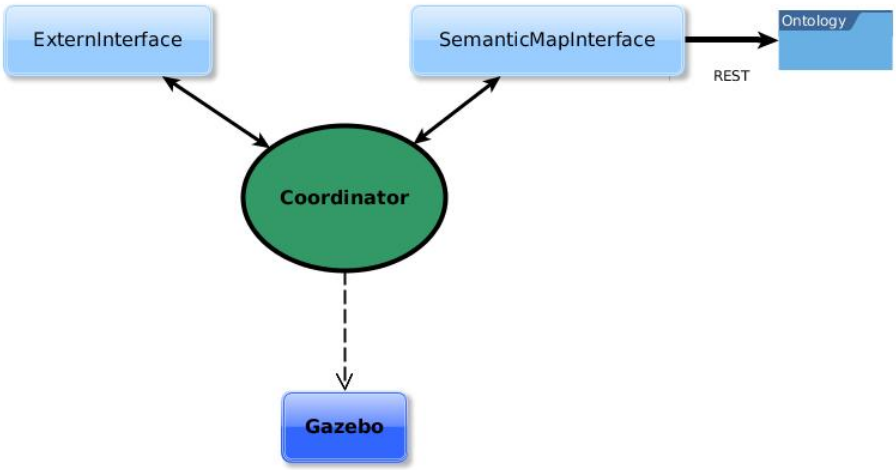


Figure 13: Coordinator Node

Basic operations include:

- Handles high level requests from other nodes such as visualizing or exporting the instances of objects present in the ontology.
- Tracks 3D positions of objects in the simulation,
- Notifies the ontology manager that an instance's property has changed,
- Forwards 3D spawn and delete task to Gazebo,
- Ensures consistency bewteen the Assertion Box and the simulated world.

### 4.1.3 Gazebo Nodes

The free and open source robot simulation environment provides high performance physics engines (ODE and DART) to model the real world dynamics and render 3D objects and environments. The Gazebo server gzserver executes the simulation process including physics updates. The Gazebo client runs the UI and provides a 3D environment and handy controls to modify simulation properties. These nodes provide a set of ROS API's that allows users to modify and get information about various aspects of the simulated world.

Topics can be used to set the pose and twist of a model by publishing desired model state message to /gazebo/set_model_state_topic. It is possible to retrieve model and link states Using Topics. Gazebo publishes /gazebo/link_states and /gazebo/model_states_topics, containing pose and twist information of objects in simulation with respect to the gazebo world frame. Services can be used to create/spawn and destroy models dynamically in simulation.

### 4.1.4 Extern Interface Node

This node has been implemented to test the required specifications. It simulates external requests by publishing predefined encoded messages on a topic to which the coordinator is subscribed. The supported operation are listed in section 1.1

## 4.2 Test cases

The following test cases have been performed:

- Initialization from non empty ontology (TBox and ABox),
- Retrieve collection of intances and render 3D models in Gazebo,
- Request a detailed list of properties about active entities,
- Manually drag objects in scene and sync new properties with ABox,
- Request Instances enumeration from ExternalInterface,
- Request deletion of entity,
- Request insertion of default instance,
- Request insertion of instance with specified type, spacial and lexical property,
- Request export to specified file,
- Perform a consistency check.

# 5 The Application

The application consists of a number of indipendent nodes that comprise a graph. Each node sends and receives information to and from other nodes of the graph using *Topics*. The communication between nodes strongly relies on a publish/subscribe mechanism useful to exchange data in a distributed system.

## 5.1 Use cases

### 5.1.1 Initialization

The application is launched by executing the init.launch file. The Roslaunch tool allows to launch multiple ROS nodes as well as set several parameters for the simulation environment. the initialization process brings up the master node, roscore, the coordinator, the semanticMapInterface and Gazebo.

Once initialized, the SemanticMapInterface loads from a specified absolute path the Terminology Box and the Assertions Box as Ontology Models.

```
/**
 * Importing Tbox
 */
 tbox = ModelFactory.createOntologyModel( OntModelSpec.OWL_MEM );
 OntDocumentManager dm_tbox = tbox.getDocumentManager();
 dm_tbox.addAltEntry(SOURCE+TBOX_FILE,"file:"+TBOX_FILE);
 tbox.read(SOURCE+TBOX_FILE,"RDF/XML");

 /**
 * Importing Abox
 */
 abox = ModelFactory.createOntologyModel( OntModelSpec.OWL_MEM);
 OntDocumentManager dma = abox.getDocumentManager();
 dma.addAltEntry( SOURCE + ABOX_FILE , "file:" + ABOX_FILE);
 abox.read(SOURCE + ABOX_FILE,"RDF/XML");
```

The reasoner API supports the notion of specializing a reasoner by binding it to a set of schema or ontology data using the bindSchema call. The specialized reasoner can then be attached to different sets of instance data using bind calls. It is worth noting that in this project the schema (TBox) and instance (ABox) data were saved in two separate files.

```
Reasoner reasoner = ReasonerRegistry.getOWLReasoner();
reasoner = reasoner.bindSchema(tbox);
OntModelSpec ontModelSpec=OntModelSpec.OWL_MEM_MICRO_RULE_INF;
ontModelSpec.setReasoner(reasoner);
InfModel infmodel = ModelFactory.createInfModel(reasoner,abox);
```

This is equivalent to an Ontology Model with Reasoner capabilities specialized on the ABox.

```
infModel = ModelFactory.createOntologyModel( ...
    OntModelSpec.OWL_MEM_MICRO_RULE_INF, abox);
```

Typically the ontology languages used with the semantic web allow constraints to be expressed, the validation interface is used to detect when such constraints are violated by some data set. To test for inconsistencies with a data set using a reasoner the InfModel.validate() interface. This performs a global check across the schema and instance data looking for inconsistencies.

```
1  /**
2   * Consistency Check. Returns true if passed
3   */
4   private static boolean performConsistencyCheckWith(InfModel inf) {
5   boolean res = false;
6
7   ValidityReport validity = inf.validate();
8   if (validity.isValid()) {
9      System.out.println(""+ NODE_NAME + "\tConsistency Check:\n Passed\n");
10     res = true;
11  } else {
12     System.out.println(""+ NODE_NAME + "\tConsistency Check:\n Conflicts\n");
13     for (Iterator i = validity.getReports(); i.hasNext(); ) {
14         System.out.println(" - " + i.next());
15     }
16  }
17  return res;
18 }
```

When the Coordinator is initialized it sends on topic called Bridge an init request. The request is captured by the SemanticMap and the *getAllInstances*(*OntModel*) method is called.

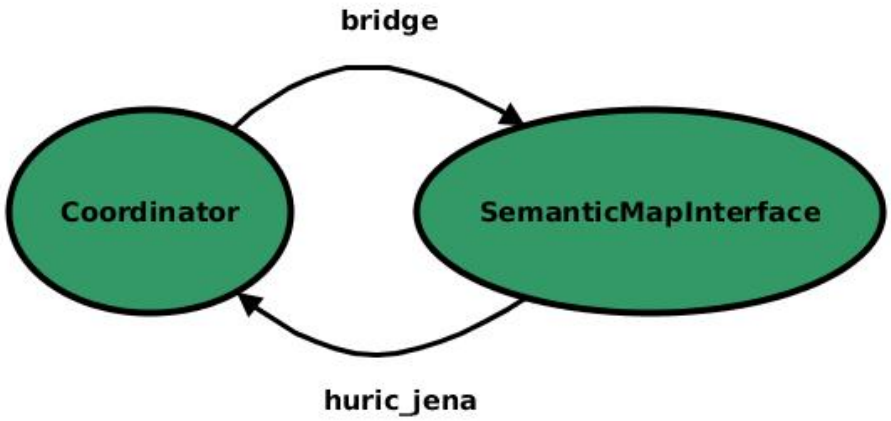


Figure 14: Data exchange between Coordinator and SemanticMapInterface

A collection of instances is retrieved and saved in a HashMap. This method performs the following SPARQL query which returns all Furniture and Drink[1] entities.

[1]Furniture and Drink are classes defined in the Terminology Box

```
String queryString = "PREFIX rdf: ...
    <http://www.w3.org/1999/02/22-rdf-syntax-ns#>" +
                "prefix rdfs: <"+RDFS.getURI()+">\n" +
                "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> " +
                "PREFIX hasPosition: <" + NS + POSITION +"> " +
                "PREFIX hasRef: <" + NS + PREF_REF +"> " +
                "prefix semantic_mapping_domain_model: <" + DOMAIN_MODEL_NS + ...
                    "#> \n"+
                "prefix semantic_mapping_1: <" + SEMANTIC_MAP_NS + "#> \n"+

                "PREFIX coordx: <" + NS + COORD_X +"> " +
                "PREFIX coordy: <" + NS + COORD_Y +"> " +
                "PREFIX coordz: <" + NS + COORD_Z +"> " +
                "PREFIX prefRef: <" + NS + LEXICAL +"> " +


                "SELECT DISTINCT ?uri ?class ?x ?y ?z ?lex "+
                "WHERE {" +
                    "{"+
                    "?uri a ?class ." +
                    "?class rdfs:subClassOf ...
                        semantic_mapping_domain_model:Furniture ."+
                    "?uri hasPosition: ?pos ." +
                    "?uri hasRef: ?ref ." +
                    "?ref prefRef: ?lex ." +
                    "?pos coordx: ?x . " +
                    "?pos coordy: ?y . " +
                    "?pos coordz: ?z " +  "} UNION {"+
                    "?uri a ?class ." +
                    "?class rdfs:subClassOf ...
                        semantic_mapping_domain_model:Drink ." +
                    "?uri hasPosition: ?pos ." +
                    "?uri hasRef: ?ref ." +
                    "?ref prefRef: ?lex ." +
                    "?pos coordx: ?x . " +
                    "?pos coordy: ?y . " +
                    "?pos coordz: ?z " +  "}"+
"}" ;
```

The resulting information are embedded in a message and sent on a topic called *Huric_jena*.

The Coordinator Node receives and parses the message. It then calls a special service that allows to create or deleted models dynamically in the simulation environment of Gazebo.

### 5.1.2 Insertion of entities

Instances of a given class can be dynamically inserted in the Assertion Box by publishing a predefined command on a topic called *extern_ commands*. One node can create an instance by specifying its super class, its spacial positions and preferred lexical reference. Another faster way include the possibility to add a Chair in fixed position. These insertion methods are issued by the ExternInterface node, captured by the Coordinator and forwarded to the SemanticMapInterface.

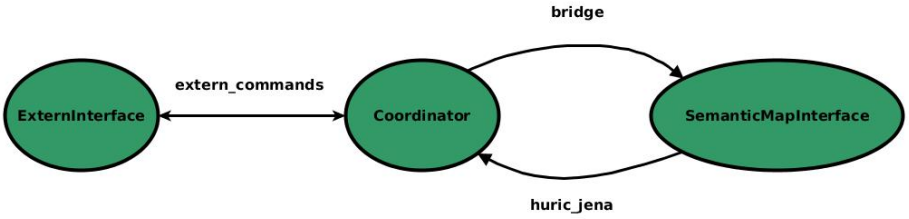


Figure 15: Data exchange between ExternInterface, Coordinator and SemanticMap-Interface

The Java Node provides two methods to insert an instance of given type to the ontology model loaded in memory:

- Triple manipulation based
- SPARQL based

Jena Ontology API provides a full set of methods to manipulate statements. The handleAddEntityRequest(ontModel,ontClass, uri, pose,lexicalReference) method is given below:

```
1  /**
2   * Handles AddEntityRequests from orchestrator using Jena API
3   *  Creates a new instance, adds properties to it and perform consistency check
4   * If test is passed, leaves the newly created instance, otherwise deletes it
5   */
6      private static boolean handleAddEntityRequest(OntModel abox, OntClass ...
           ontClass, String uriInstance, String posX,
7              String posY, String posZ, String lexicalReference){
8          boolean res = false;
9
10         OntClass prefrefClass = abox.getOntClass(NS+PREF_REF_CLASS);
11         OntClass coordinatesClass = abox.getOntClass(NS+COORDINATES_CLASS);
12
13         String uriBase = ...
               "http://www.semanticweb.org/ontologies/2016/1/semantic_mapping_1#";
14         // Create instance
15         //OntClass class1 = abox.getOntClass(NS+ontClass);
16
17         if (ontClass == null)
18             return false;
19         else {
20             // Create Individuals
21             Individual i1 = abox.createIndividual(uriInstance,ontClass);
22             Individual prefRefInd = ...
                   abox.createIndividual(uriBase+lexicalReference
23             +"_pref_ref",prefrefClass);
24             Individual coordinatesInd = ...
                   abox.createIndividual(uriBase+lexicalReference
25             +"_pref_ref",coordinatesClass);
26
27
28             // Create Datatype Property
29             DatatypeProperty lexicalRef = abox.getDatatypeProperty(NS + LEXICAL);
30             Literal ref = abox.createTypedLiteral(lexicalReference);
31             Statement refStatement = abox.createStatement(prefRefInd, ...
                   lexicalRef, ref);
32             abox.add(refStatement);
```

```
33
34              //  Bind pref reference individual to object individual
35              ObjectProperty hasPrefRef = abox.getObjectProperty(NS+PREF_REF);
36              Statement bindPrefRef = abox.createStatement(i1, hasPrefRef, ...
                    prefRefInd);
37              abox.add(bindPrefRef);
38
39
40              // Create Datatype Property for coordinate X
41              DatatypeProperty posx = abox.getDatatypeProperty(NS + COORD_X);
42              Literal posXFloat = abox.createTypedLiteral(posX);
43              Statement posXStatement = abox.createStatement(coordinatesInd, ...
                    posx, posXFloat);
44              abox.add(posXStatement);
45              // Create Datatype Property for coordinate X
46              DatatypeProperty posy = abox.getDatatypeProperty(NS + COORD_Y);
47              Literal posYFloat = abox.createTypedLiteral(posY);
48              Statement posYStatement = abox.createStatement(coordinatesInd, ...
                    posy, posYFloat);
49              abox.add(posYStatement);
50              // Create Datatype Property for coordinate X
51              DatatypeProperty posz = abox.getDatatypeProperty(NS + COORD_Z);
52              Literal posZFloat = abox.createTypedLiteral(posZ);
53              Statement posZStatement = abox.createStatement(coordinatesInd, ...
                    posz, posZFloat);
54              abox.add(posZStatement);
55
56
57              //  Bind position individual to object individual
58              ObjectProperty hasPosition = abox.getObjectProperty(NS+POSITION);
59              Statement bindPose = abox.createStatement(i1, hasPosition, ...
                    coordinatesInd);
60              abox.add(bindPose);
61
62              // Now perform consistency check
63
64              InfModel infModel = ModelFactory.createOntologyModel( ...
                    OntModelSpec.OWL_MEM_MICRO_RULE_INF, abox);
65              res = performConsistencyCheckWith(infModel);
66          }
67
68          return res;
69  }
```

The second method is called AddEntityRequest(abox,ontclass,uri,pose,lexicalReference) and it is based on a SPARQL query:

```
1  /**
2   * Handles AddEntityRequests using SPARQL
3   *  Creates a new instance, adds properties to it and perform consistency check
4   * If test is passed, leaves the newly created instance, otherwise deletes it
5   */
6   private static boolean AddEntityRequest(OntModel abox, OntClass ontClass, ...
        String uriInstance, String posX,
7               String posY, String posZ, String lexicalReference){
8   boolean res = true;
9
10  String uri_Instance[] = uriInstance.split("#");
11
12  if (ontClass == null) {
13     res = false;
14     System.out.print("\n"+ NODE_NAME + "\t[ Add Entity ] Class problem\n");
15  } else {
```

```
16              String queryString = "" +
17              "prefix rdfs: <"+ RDFS.getURI() +">\n" +
18              "prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> \n"+
19              "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> "
20
21              + "prefix semantic_mapping_domain_model: <" + DOMAIN_MODEL_NS + ...
                    "#> \n"
22              + "prefix semantic_mapping: <" + SEMANTIC_MAP_NS + "#> \n"
23              + "PREFIX class: <"+ ontClass.getURI() +">\n"
24
25
26              + "insert data { semantic_mapping:"+uri_Instance[1] +" rdf:type ...
                    class: . "
27
28
29              // Add hasPosition Irreflexive ObjectProperty
30              + "semantic_mapping:" + uri_Instance[1] + " ...
                    semantic_mapping_domain_model:hasPosition semantic_mapping:" ...
                    + uri_Instance[1]
31              + "_coordinates . "
32
33              // Add Instance Coordinates
34              + "semantic_mapping:" + uri_Instance[1]+ "_coordinates rdf:type ...
                    semantic_mapping_domain_model:Coordinates . "
35
36              // Add datatype Property
37              + "semantic_mapping:" + uri_Instance[1] + "_coordinates ...
                    semantic_mapping_domain_model:float_coordinates_x \""
38              + posX + "\"^^xsd:float . "
39              + "semantic_mapping:" + uri_Instance[1] + "_coordinates ...
                    semantic_mapping_domain_model:float_coordinates_y \"" + posY
40              + "\"^^xsd:float . "
41              + "semantic_mapping:" + uri_Instance[1] + "_coordinates ...
                    semantic_mapping_domain_model:float_coordinates_z \"" + posZ
42              + "\"^^xsd:float . "
43
44              // Add hasPreferredReference ObjectProperty
45              + "semantic_mapping:" + uri_Instance[1] + " ...
                    semantic_mapping_domain_model:hasPreferredReference ...
                    semantic_mapping:" + uri_Instance[1]
46              + "_preferredReference . "
47
48              // Create Instance Lexical Reference
49              + "semantic_mapping:" + uri_Instance[1] + "_preferredReference ...
                    rdf:type semantic_mapping_domain_model:PreferredReference . "
50
51              + "semantic_mapping:" + uri_Instance[1] + "_preferredReference ...
                    semantic_mapping_domain_model:lexicalReference \"" + ...
                    lexicalReference
52              + "\"^^xsd:string . " + "} \n ";
53
54              UpdateAction.parseExecute(queryString, abox);
55
56              // Check inconsistencies
57              InfModel infModel = ModelFactory.createOntologyModel( ...
                    OntModelSpec.OWL_MEM_MICRO_RULE_INF, abox);
58              res = performConsistencyCheckWith(infModel);
59          }
60
61          return res;
62  }
```

Once the instance has been inserted into the ontology model, the collection of new entities is once again sent on the *huric_jena* topic and captured by the coordinator which invokes

the Gazebo service to render the 3D model of the newly created instances at the provided position in space.

## 5.2 Exporting Ontology

## 5.3 Future works

The following points assume that the robot is equipped with a spoken command recognition

Lu4r

PointCloud

# List of Figures



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