Web Ontology Language (OWL)

Máster Universitario en Inteligencia Artificial

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Material

http://delicias.dia.fi.upm.es/wiki/index.php/MasterRD11-12

Week 9. 8/11/2011. OWL (Mikel Egaña Aranguren)

http://mikeleganaaranguren.wordpress.com/teaching/

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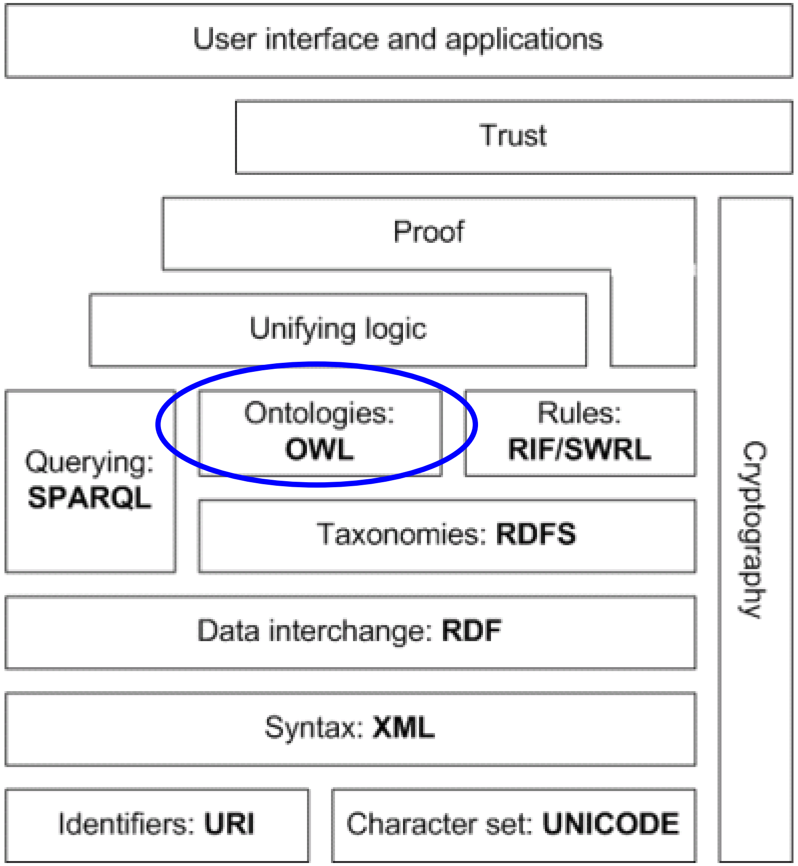
Introduction to OWL

OWL is a Knowledge Representation language proposed by the W3C as a standard to codify ontologies in a prospective Semantic Web



OWL is based in Description Logics

We can represent a knowledge domain computationally in an OWL ontology, in order to:

Apply automated reasoning: infer “new” knowledge, queries, consistency, classify entities against the ontology, …

Integrate knowledge from different resources

Everything about OWL 2: http://www.w3.org/standards/techs/owl

Document overview: http://www.w3.org/TR/2009/REC-owl2-overview-20091027/

Primer: http://www.w3.org/TR/2009/REC-owl2-primer-20091027/

Manchester OWL + Protégé tutorial (Copied some examples :-): http://owl.cs.manchester.ac.uk/tutorials/protegeowltutorial/

OWL versions:

"OWL 1": OWL lite, OWL DL, OWL Full

OWL 1.1

OWL 2 profiles: OWL EL, OWL QL, OWL RL

OWL syntaxes

OWL syntaxes

For computers: RDF/XML, OWL/XML, …

RDF/XML:

```
<owl:Class rdf:about="#arm">
   <rdfs:subClassOf>
    <owl:Restriction>
        <owl:onProperty rdf:resource="#part_of"/>
        <owl:someValuesFrom rdf:resource="#body"/>
    </owl:Restriction>
   </rdfs:subClassOf>
</owl:Class>
```

For humans: Manchester OWL Syntax, functional, …

Manchester OWL Syntax: arm subClassOf art_of some body

http://www.co-ode.org/resources/reference/manchester_syntax/

OWL semantics

An OWL ontology comprises:

<u>Entities</u>: the named elements from the knowledge domain, created by the ontology creator. Entities are identified using URIs (To work in a web setting)

<u>Axioms</u>: axioms relate the entities to each other using the OWL logic vocabulary

An OWL ontology can import other ontologies (owl:import): the entities of the imported ontology can be referenced by axioms on our ontology

OWL is "Axiom-centric"

Entities only "exist" as part of axioms, and therefore the only way of creating an entity in an ontology is by adding an axiom that refers to it. We cannot create the class A, but we can state that A subClassOf owl:Thing

!!!

There are three types of entities in an OWL ontology:

Individuals

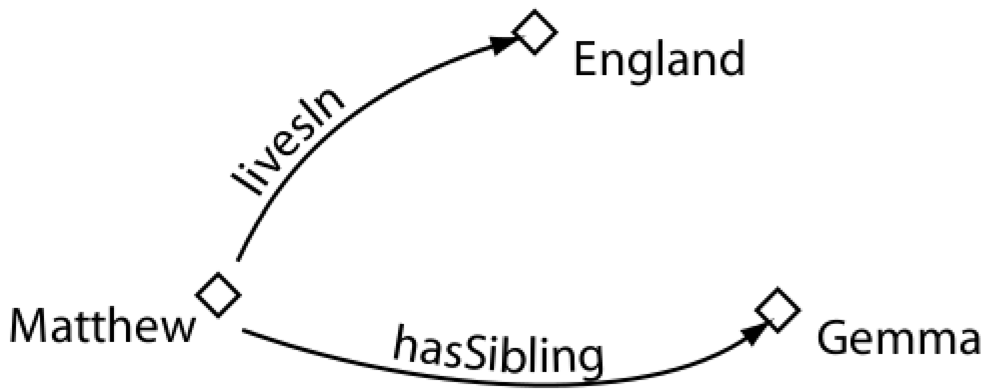
Properties

Classes

Individuals: the objects of the knowledge domain

(Tutorial Manchester)

Properties: they can be used to link individuals in binary relations



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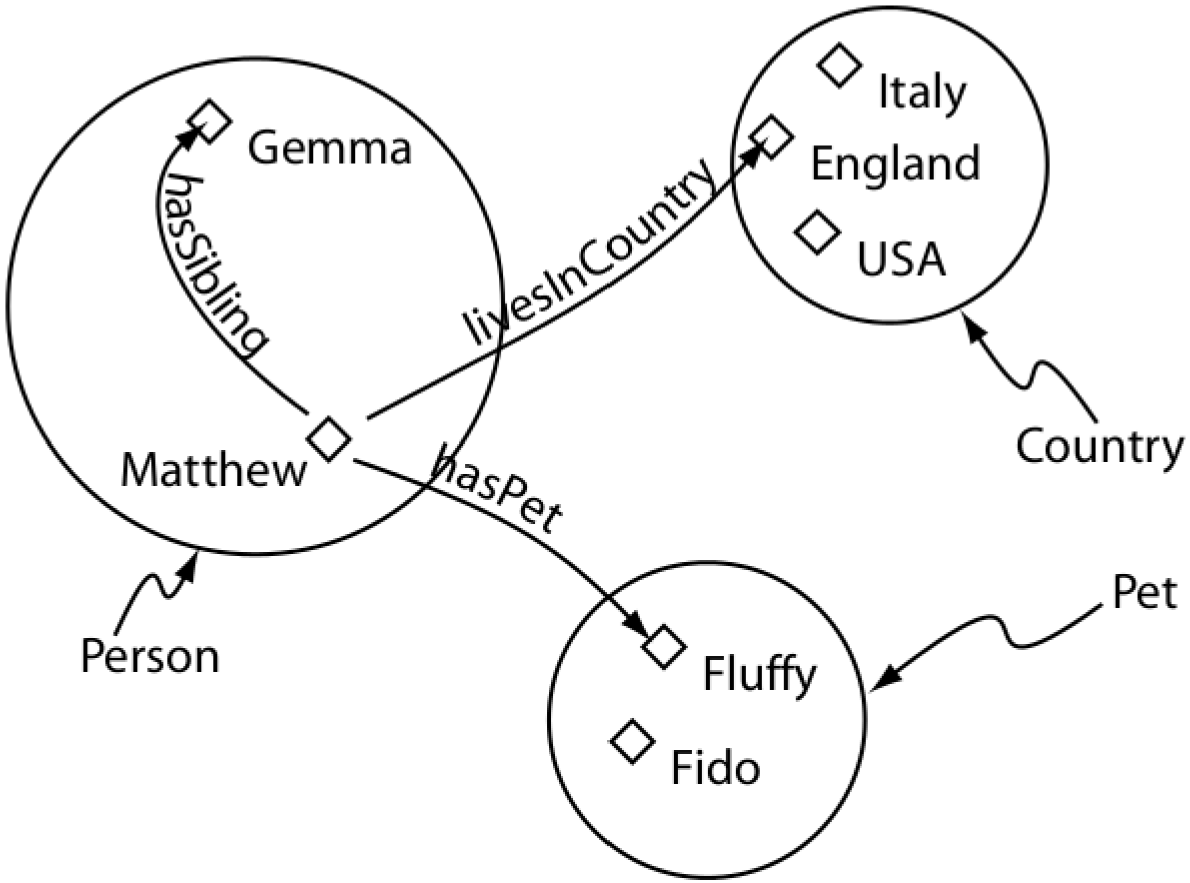
Classes: sets of individuals with common characteristics



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An OWL ontology with individuals and classes is a Knowledge Base

Knowledge Base (KB): Abox + Tbox

TBox (Terminological Box): ~schema (~ classes)

Abox (Assertional Box): ~data (~ individuals)

OWL works under the Open World Assumption (OWA)

Data Base (Closed World Assumption): the information not mentioned is false (Negation as Failure)

Knowledge Base (Open World Assumption): the information not mentioned is unknown (Can be true or false)

!!!

Pedro has spanish nationality

¿Does Pedro have british nationality?

CWA (DB): No

OWA (OWL KB): We don't know (Pedro can have double nationality). Till we assert that Pedro can only have one nationality, OWL will assume he can have more than one

OWA advantage: we can add new knowledge (e.g. New nationalities) easily, we don't have to “change the schema”

OWA is good for settings in which our knowledge will always be incomplete: open systems like the (Semantic) Web

In OWL there is no Unique Name Assumption (UNA)

The fact that two entities have different URIs does not imply that they are different entities

We have to explicitly assert, if we want to, that two entities are different from each other

In the (Semantic) Web, different resources talk about the same entity

!!!

No UNA + OWA:

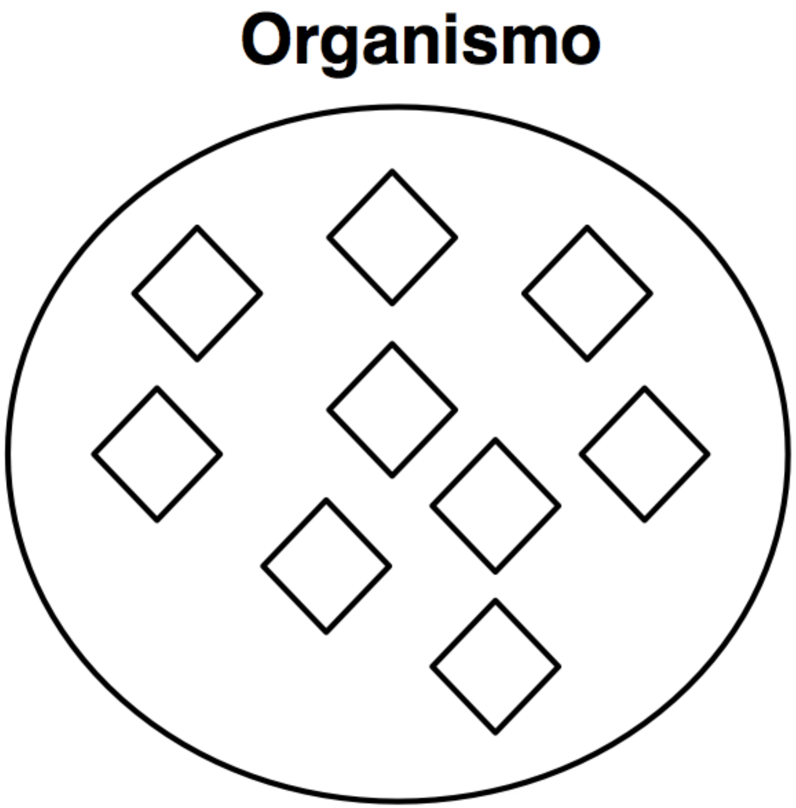
Building an ontology in OWL is like pruning a space in which by default everything is possible (OWA) and all the entities are the same (!UNA)

Such prunning is performed by adding axioms that limit the possible facts and make entities different to each other

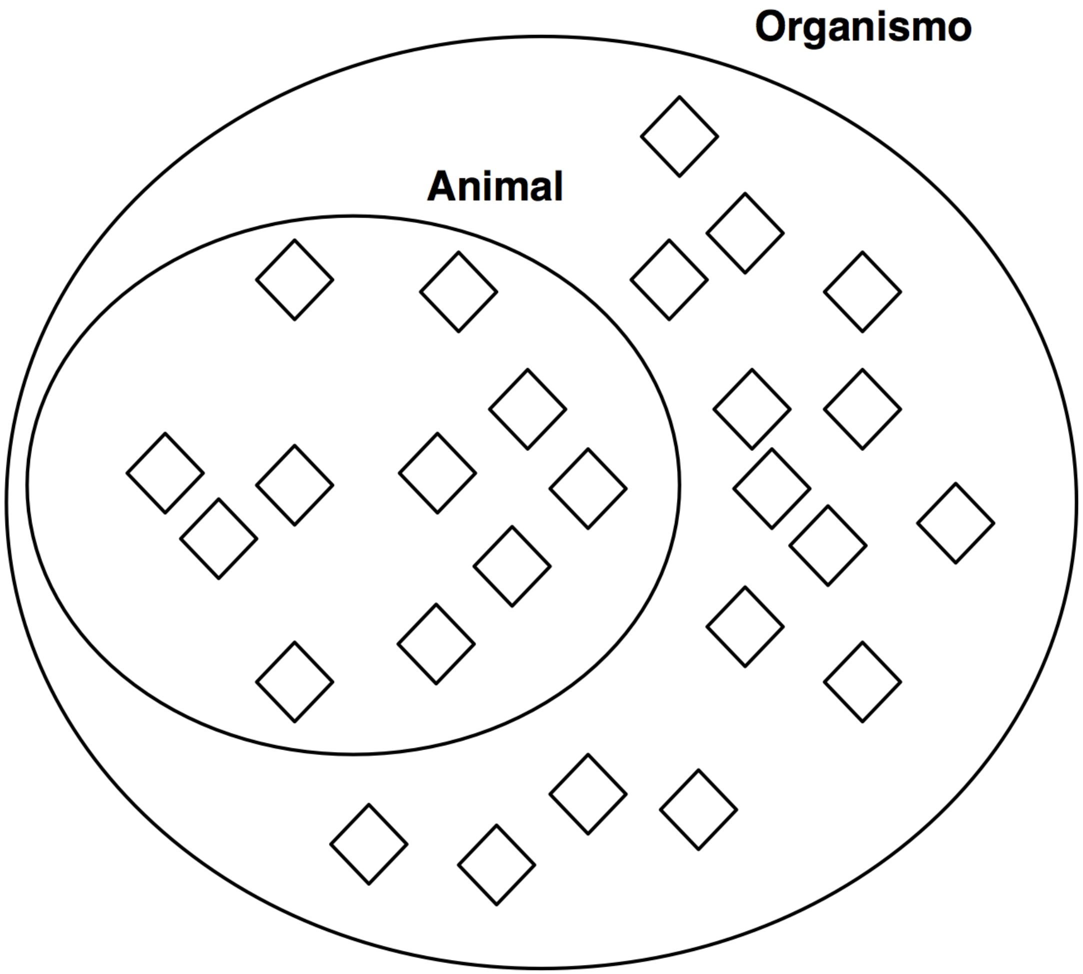
!!!

Classes

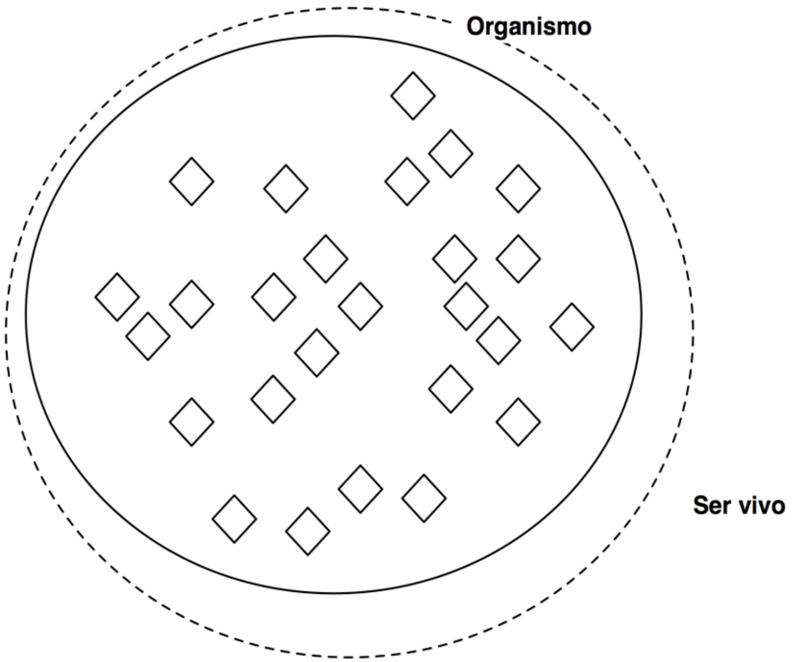
Classes: Sets of individuals



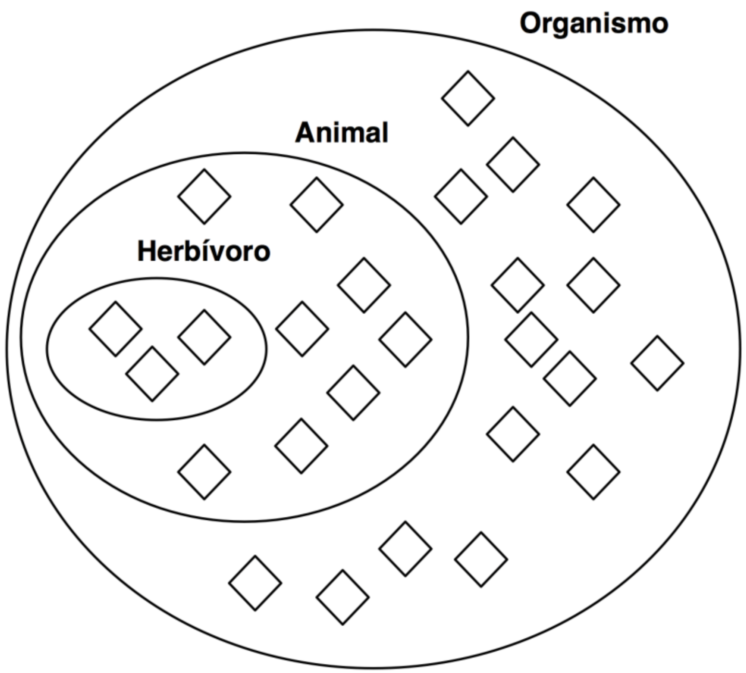
Classes can be subclasses of other classes: all the instances of the subclass are also instances of the superclass (But no the other way around)

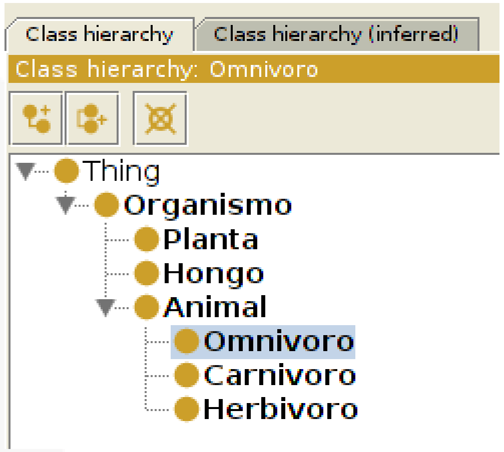


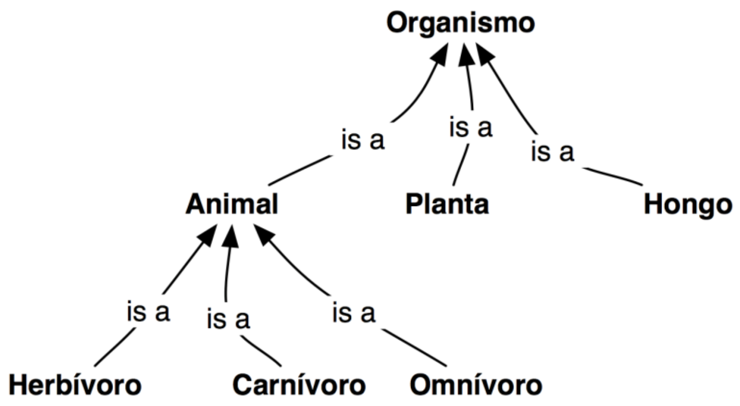
Classes are equivalent if the extent of their sets is exactly the same: all the instances of A are also instances of B and the other way around



A taxonomy can be built combining different class-subclass axioms







In order to define the qualities that the individuals of a class must hold to be members of that class, *restrictions* on the number and type of binary relations are used

Thus, the restrictions define the conditions that must be fulfilled to be a member of a given class

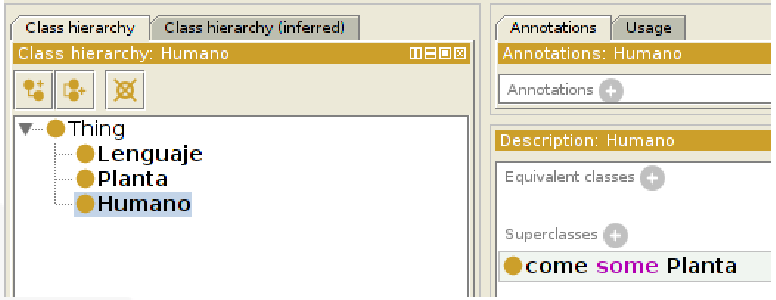
For example, we can state (In our ontology!) that in order to be human something must eat plants

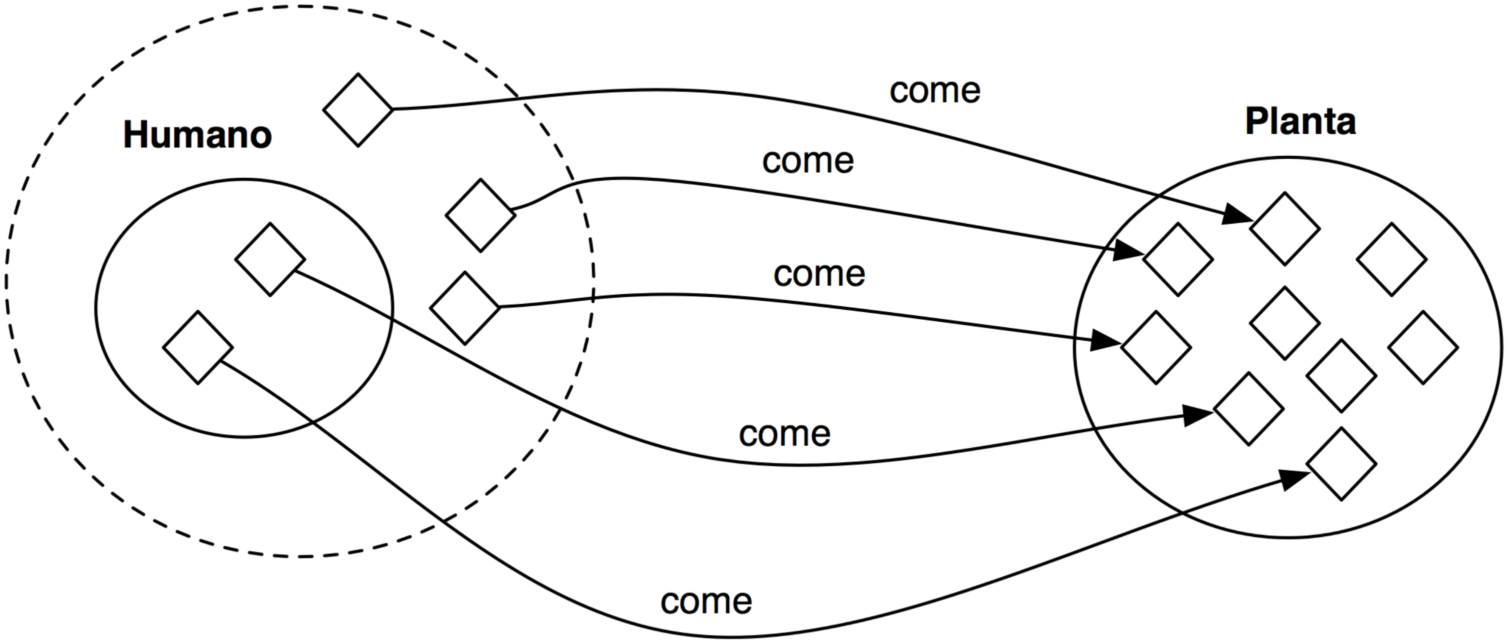
Eating plants is a *necessary condition* to be human: all the humans eat plants, but there are other organisms that also eat plants that are not humans

We can also define a *necessary and sufficient* condition: producing language is a unique quality of humans: if we find an individual (Organism) capable of producing language we can infer that is human, since no other organism does it

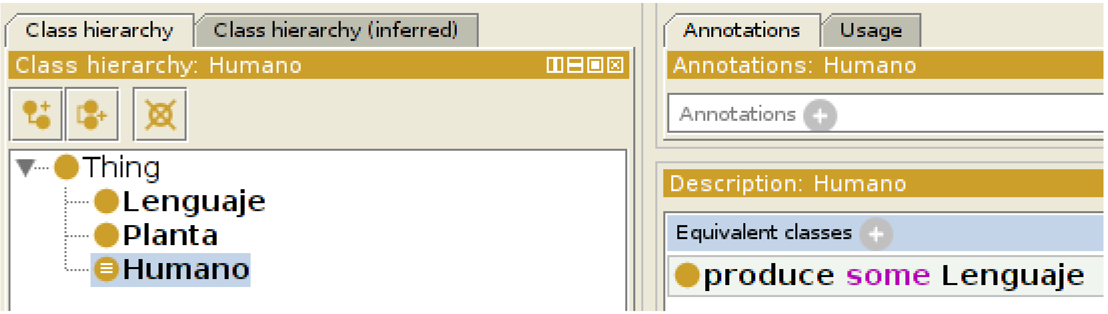
Conditions are anonymous classes: the named class we are defining with such conditions can be a subclass (Necessary) or equivalent class (Necessary and sufficient) to the anonymous class

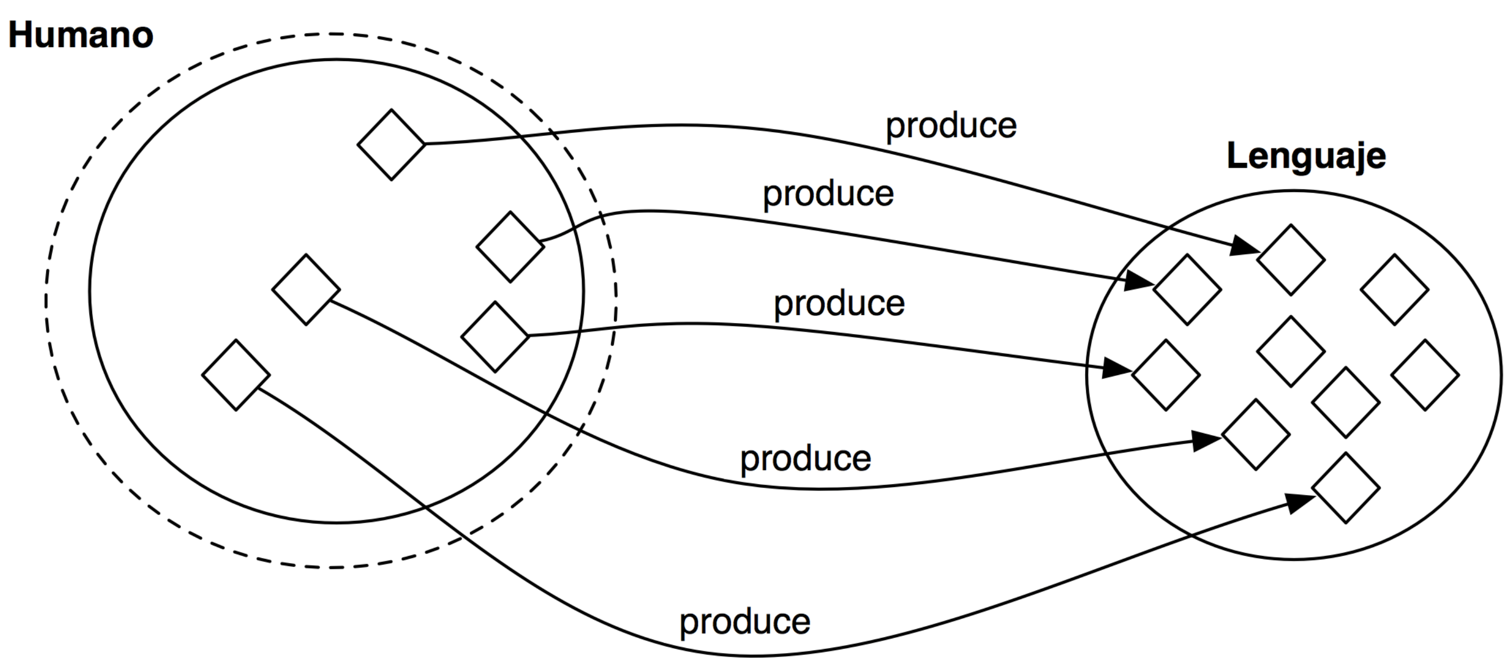
The class Humano is a subclass (N) of the anonymous class comprised of the individuals that have at least one come binary relation with an individual of the class Planta





The class Humano is equivalent (N+S) to the anonymous class comprised of the individuals that have at least on relation with the property produce with and individual of the class Lenguaje



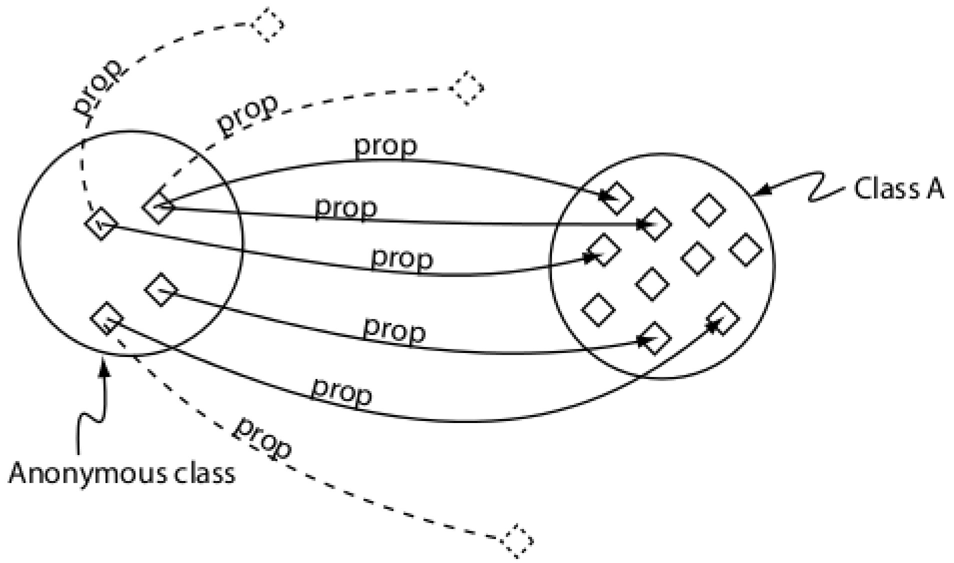


The classes with necessary and sufficient conditions are *defined* classes, and they are exploited for automated reasoning

The classes with only necessary conditions are *primitive* classes

Existential restrictions

owl:someValuesFrom: the anonymous class comprised of the individuals that, ammongst other things, have at least one relation to an individual of a given class with a given property: humano subClassOf come some Planta



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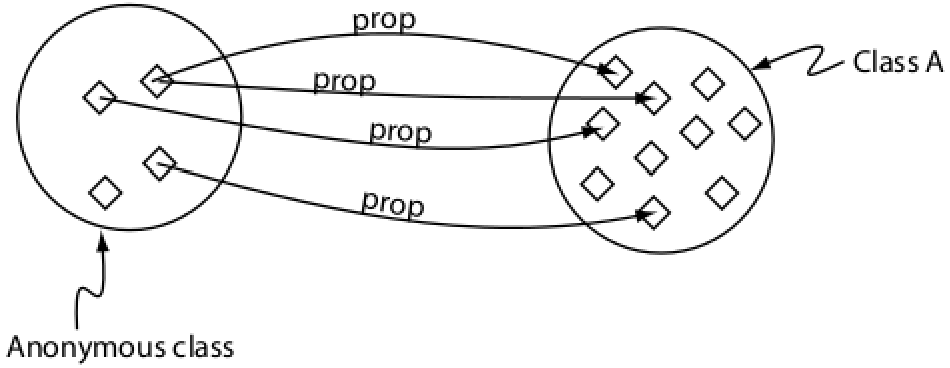
Universal restriction

owl:allValuesFrom: the anonymous class comprised of the individuals that, if having a relation with a given property, must be to an individual of a concrete class or *none*: humano subClassOf come only Organismo



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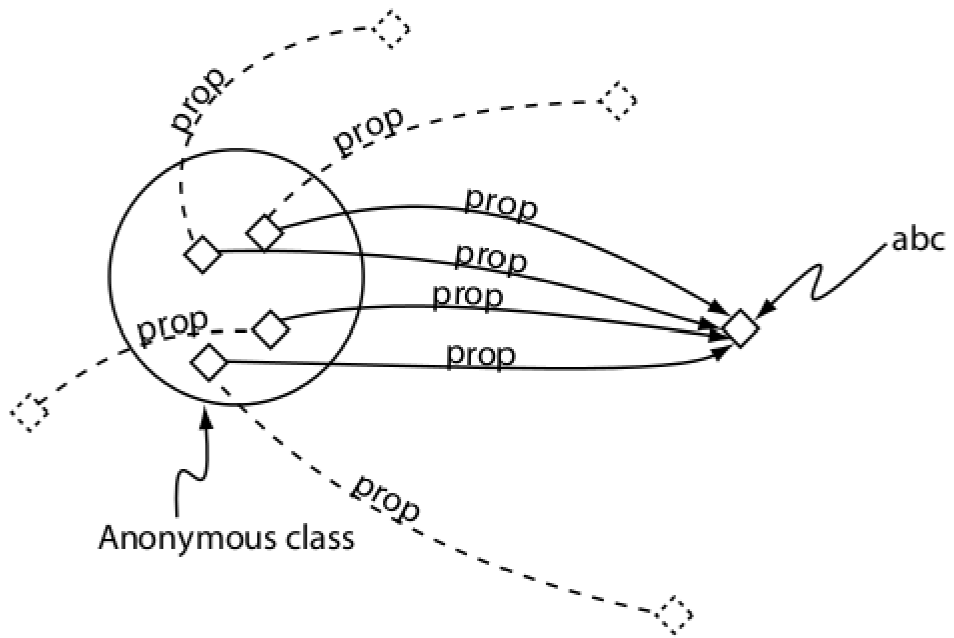
hasValue

the anonymous class comprised of the individuals that have a relation to a concrete individual humano subClassOf come value este_tomate



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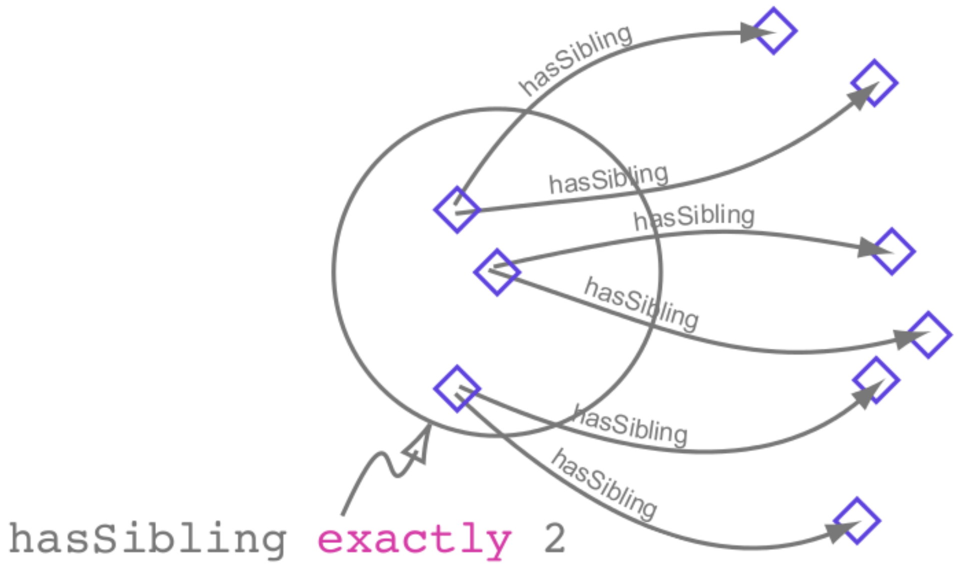
Cardinal restrictions:

Min: humano subClassOf come min 1

Max: humano subClassOf come max 5

Exactly: humano subClassOf come exactly 3



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QCR (Qualified Cardinality Constraint):

Min: humano subClassOf come min 1 Planta

Max: humano subClassOf come max 5 Planta

Exactly: humano subClassOf come exactly 3 Planta

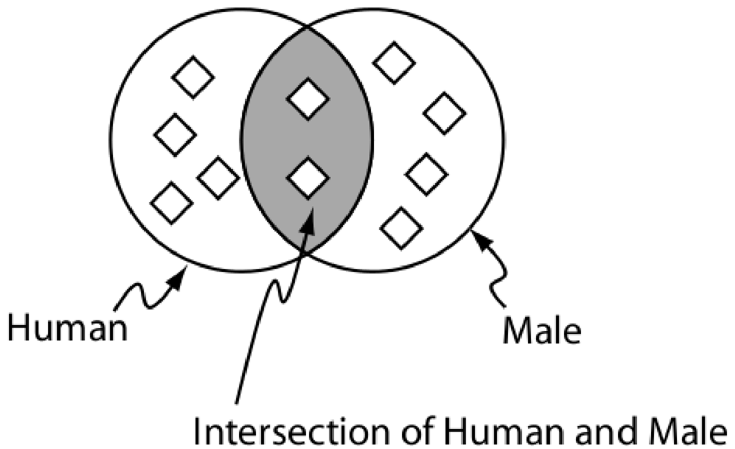
We can state that a class is different to other class (They don't have any individual in common) using disjointFrom: humano disjointFrom planta

We can state that two classes are the same (They have the same extent of individuals) using equivalentTo: humano equivalentTo persona

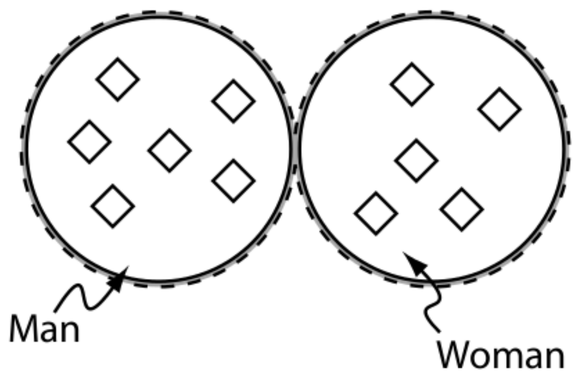
Booleans

Not: humano subClassOf not (come some electrodomestico)

And (Intersection):
man equivalentTo human and male



Or (Union):
human equivalentTo woman or man



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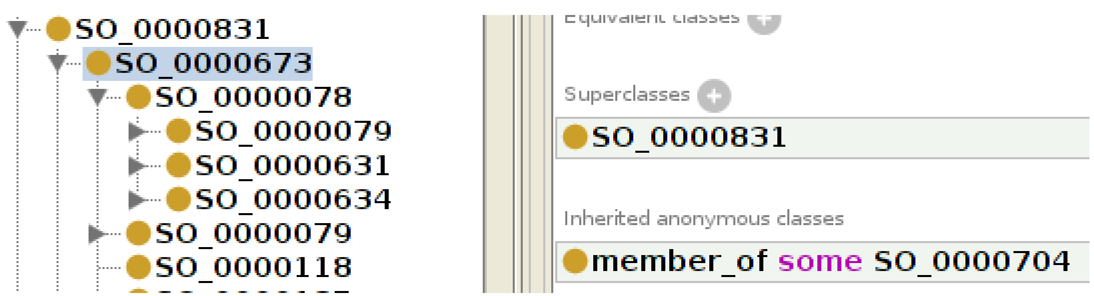
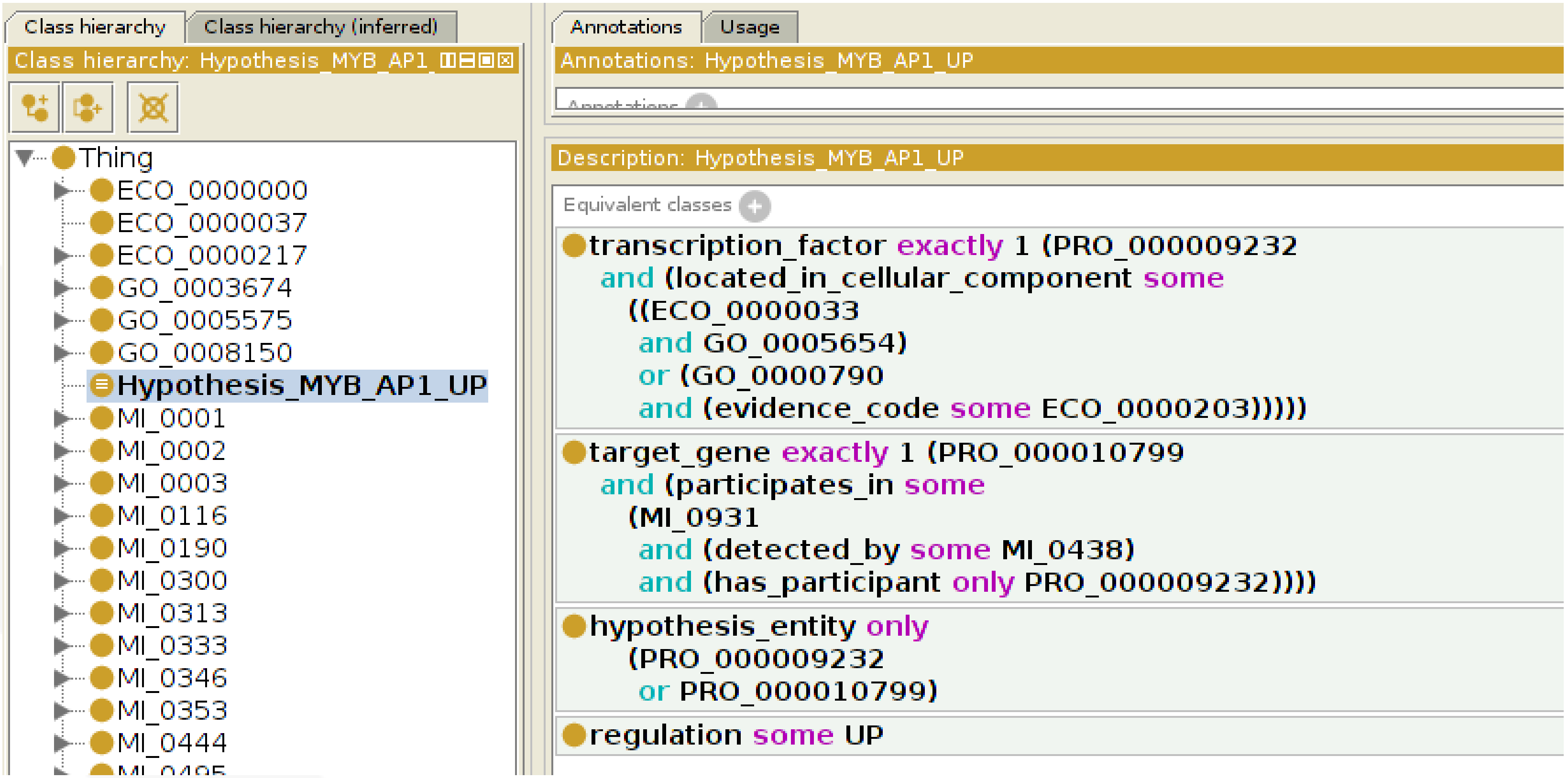
OWL semantics

In a class hierarchy, the subclass "inherits" the conditions of the superclass: it can have further conditions but not a condition that conflicts with the conditions of the superclass



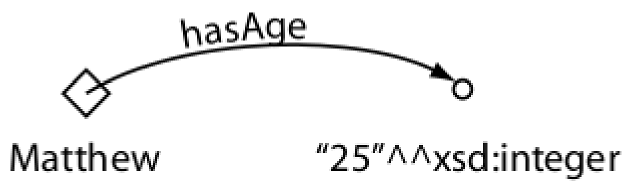
Conditions can be very complex, combining different OWL elements



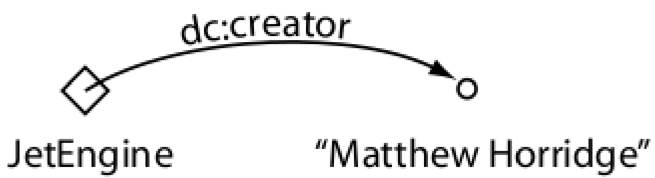
Properties

Object Properties

DataType Properties



Annotation Properties*



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Object Properties

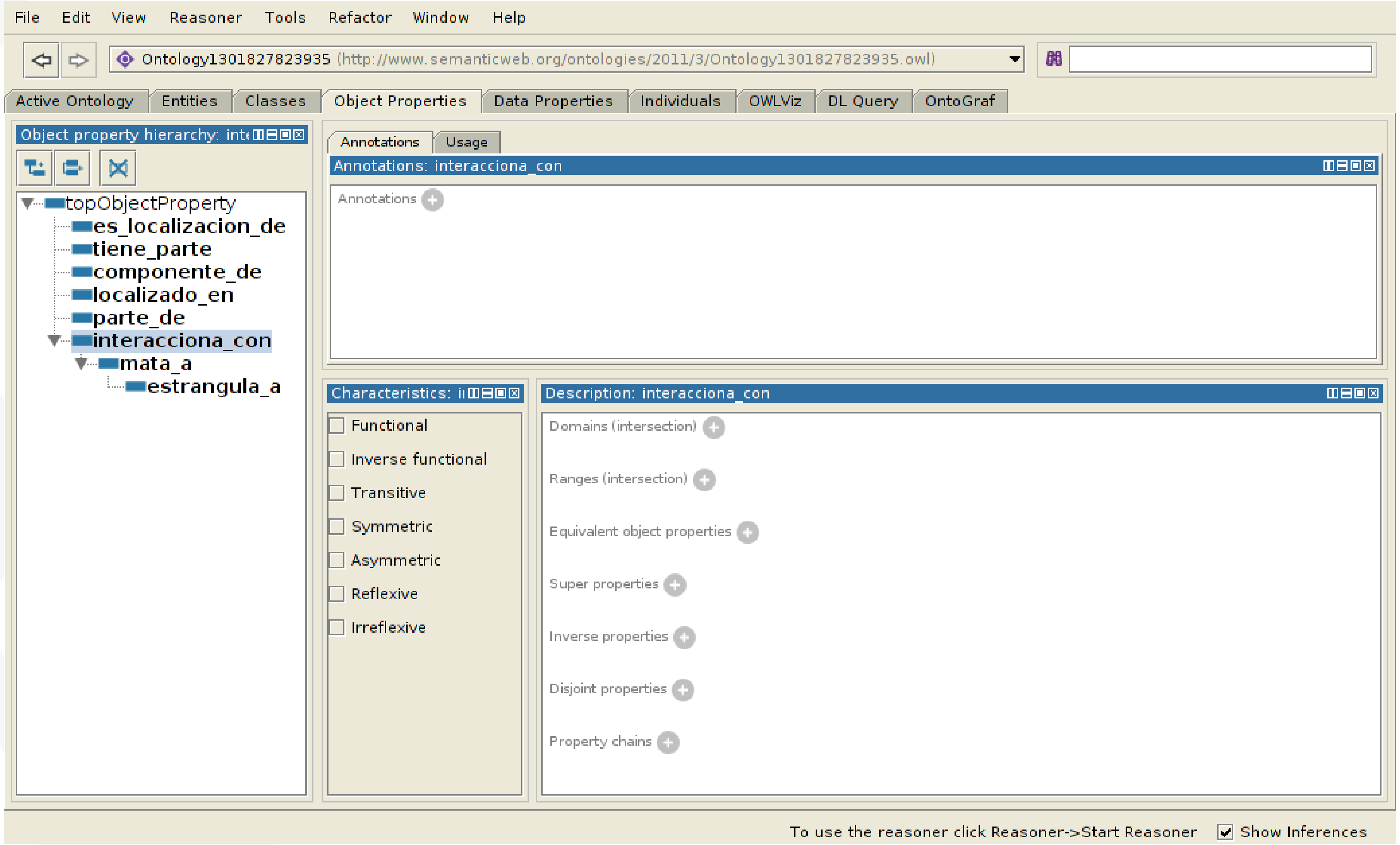
Property hierarchy:

Sub/SuperProperties

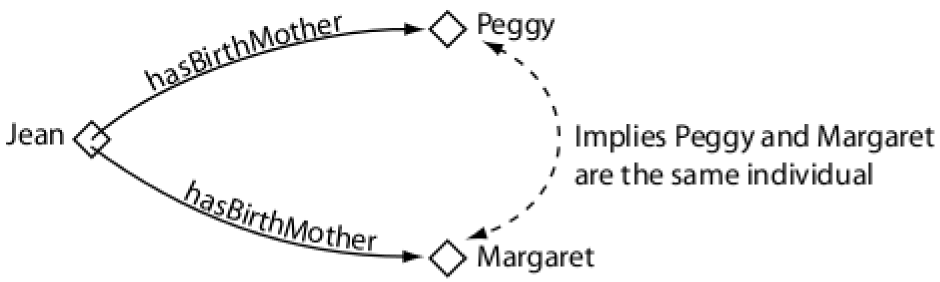
p SubPropertyOf q
If A p B, A q B
But if D q F, not D p F

Equivalent Properties

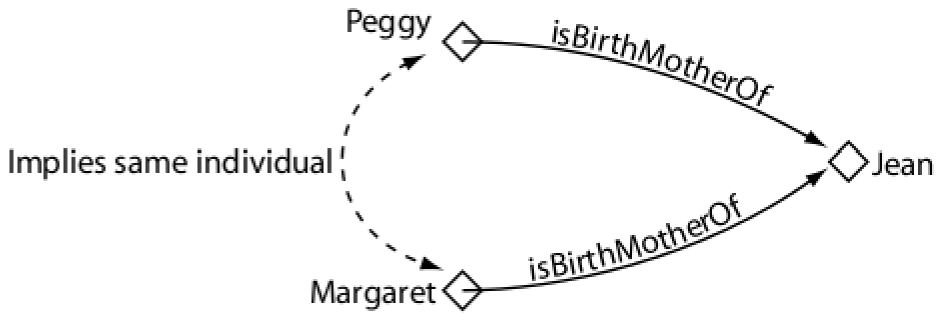
Disjoint Properties


File Edit View Reasoner Tools Refactor Window Help
Ontology1301827823935 (http://www.semanticweb.org/ontologies/2011/3/Ontology1301827823935.owl)
Active Ontology
Entities
Classes
Object Properties
Data Properties
Individuals
OWLViz
DL Query
OntoGraf
Object property hierarchy: int
topObjectProperty
es_localizacion_de
tiene_parte
componente_de
localizado_en
parte_de
interacciona_con
mata_a
estrangula_a
Annotations
Usage
Annotations: interacciona_con
Annotations
Characteristics: i
Functional
Inverse functional
Transitive
Symmetric
Asymmetric
Reflexive
Irreflexive
Description: interacciona_con
Domains (intersection)
Ranges (intersection)
Equivalent object properties
Super properties
Inverse properties
Disjoint properties
Property chains
To use the reasoner click Reasoner->Start Reasoner
Show Inferences

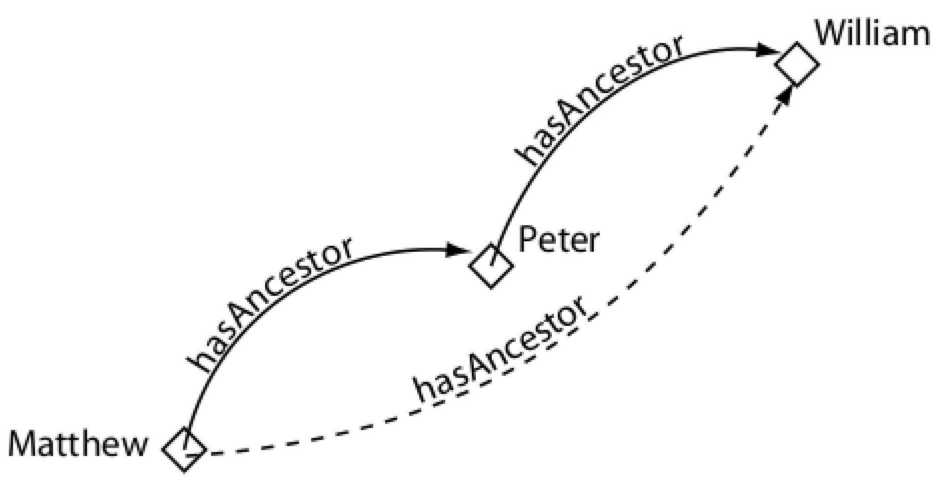
Functional



Inverse functional



Transitive



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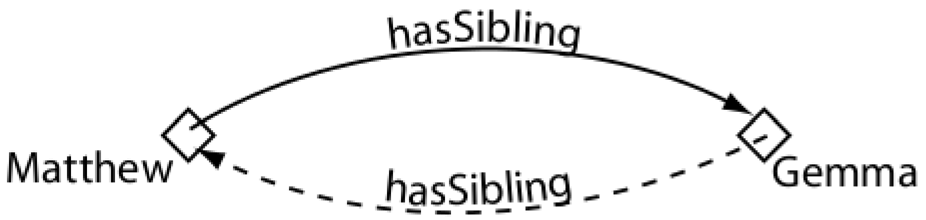
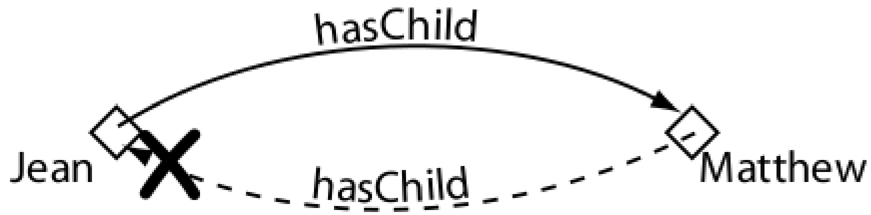
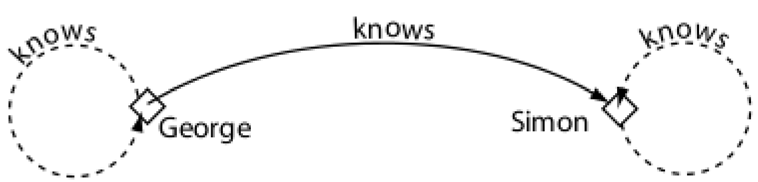
Symmetric



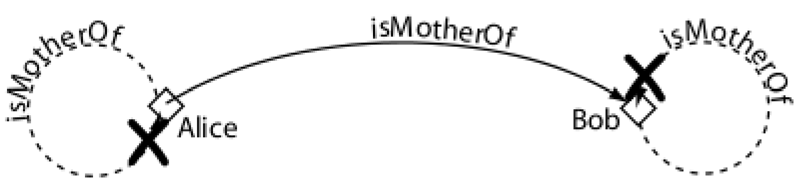
Antisymmetric*



Reflexive



Irreflexive*



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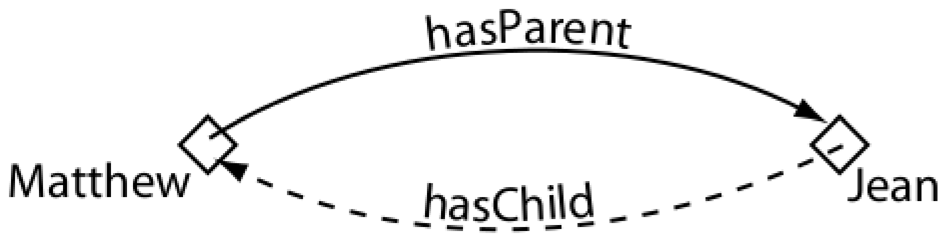
Inverse properties



(Tutorial Manchester)

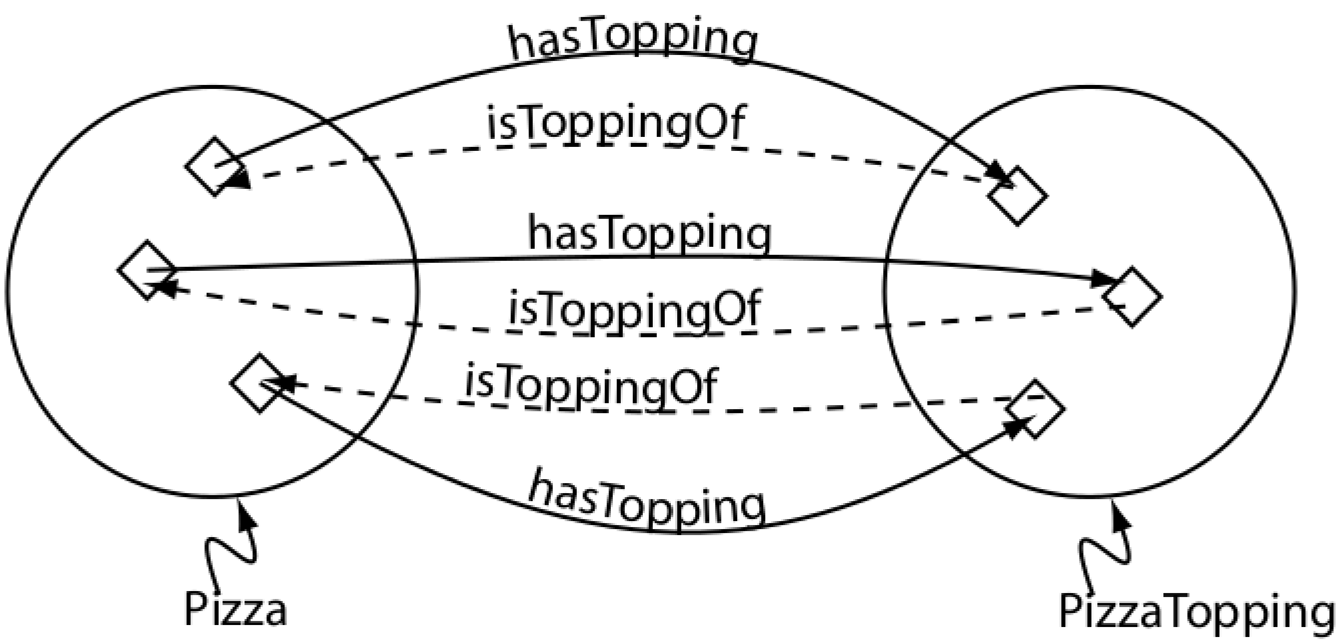
Domain and Range:

!!!

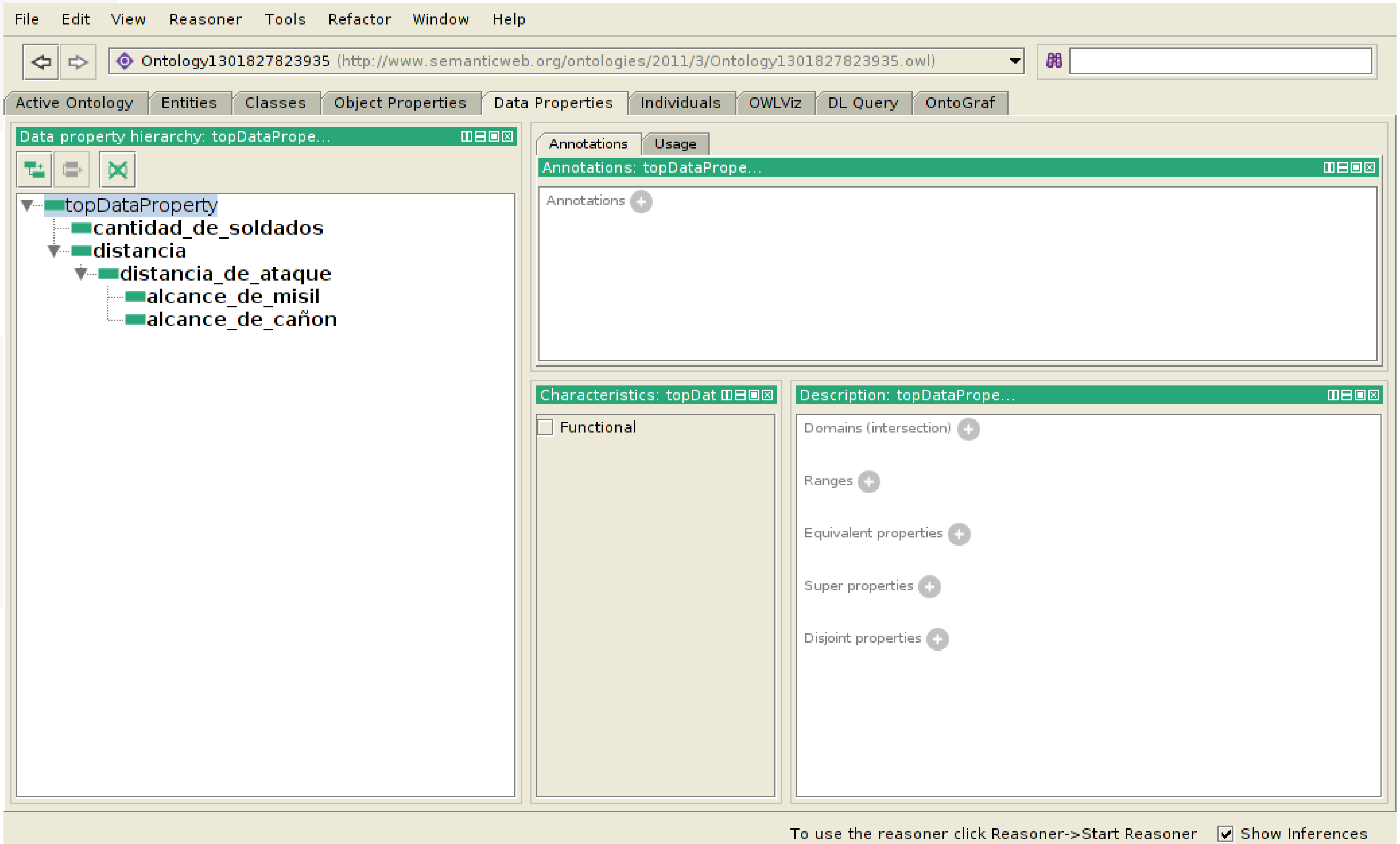
Usually classes or class unions

But any anonymous expression class can be used

They are not constraints, they are axioms



Data Type Properties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Data property hierarchy: topDataPrope...
topDataProperty
cantidad_de_soldados
distancia
distancia_de_ataque
alcance_de_misil
alcance_de_cañon
Annotations
Usage
Annotations: topDataPrope...
Annotations
Characteristics: topDat
Functional
Description: topDataPrope...
Domains (intersection)
Ranges
Equivalent properties
Super properties
Disjoint properties
To use the reasoner click Reasoner->Start Reasoner
Show Inferences

Equivalent / sub-super / disjoint

Only Functional (No transitive, inverse functional, …)

Domain: ~ Object Properties

Range:

- Built-in datatypes
- Data range expression

Annotation Properties

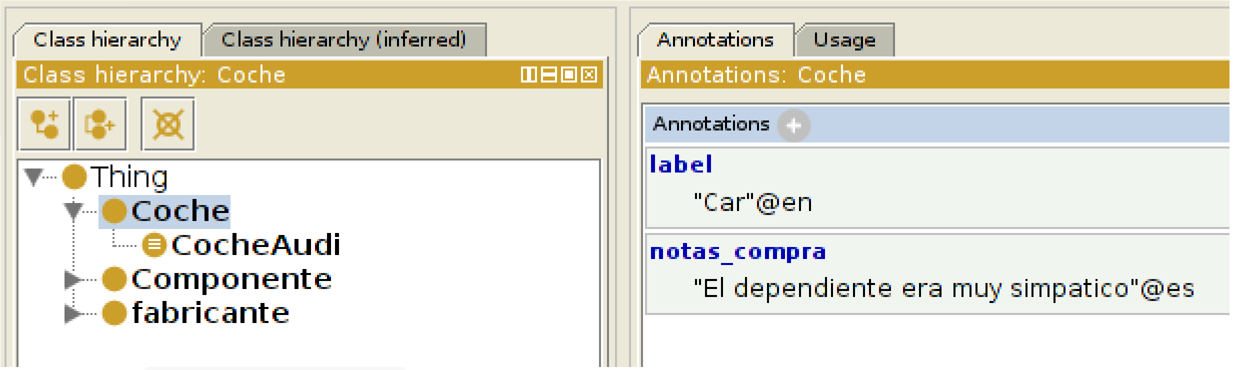
Add non-semantic annotations in natural language to entities, axioms or the ontology

rdfs:label, rdfs:comment, …

Dublin Core (http://dublincore.org/)

Custom annotation properties

Language (en, es, ...) and type (xsd:string, …)



Individuals

An individual can be a member of one or more anonymous or named classes (Types)

An individual can be the same as other individual (SameAs)

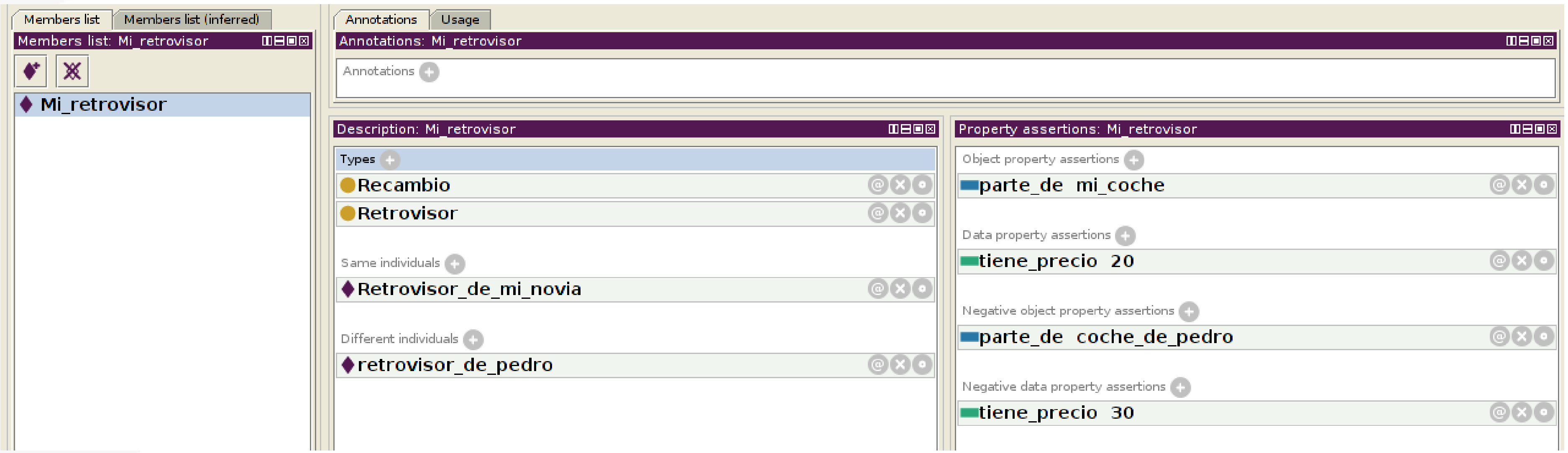
An individual can be different from another individual (DifferentFrom)

Individuals can be related in binary relations (Object Properties):

my_wheel part_of my_car
my_wheel not part_of your_car

Individuals can be related with data (Data Type properties):

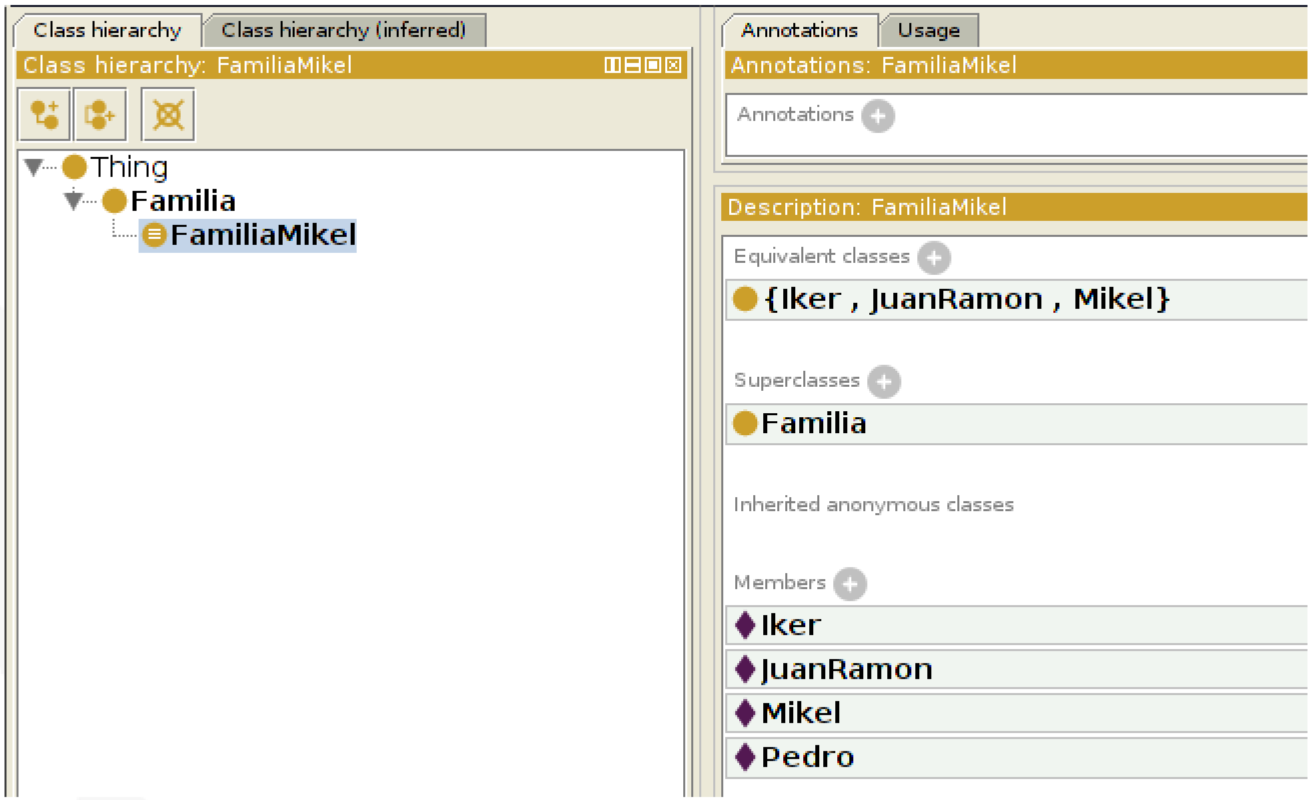
my_car has_power "90"^^xsd:positiveInteger
my_car not has_power "90"^^xsd:positiveInteger



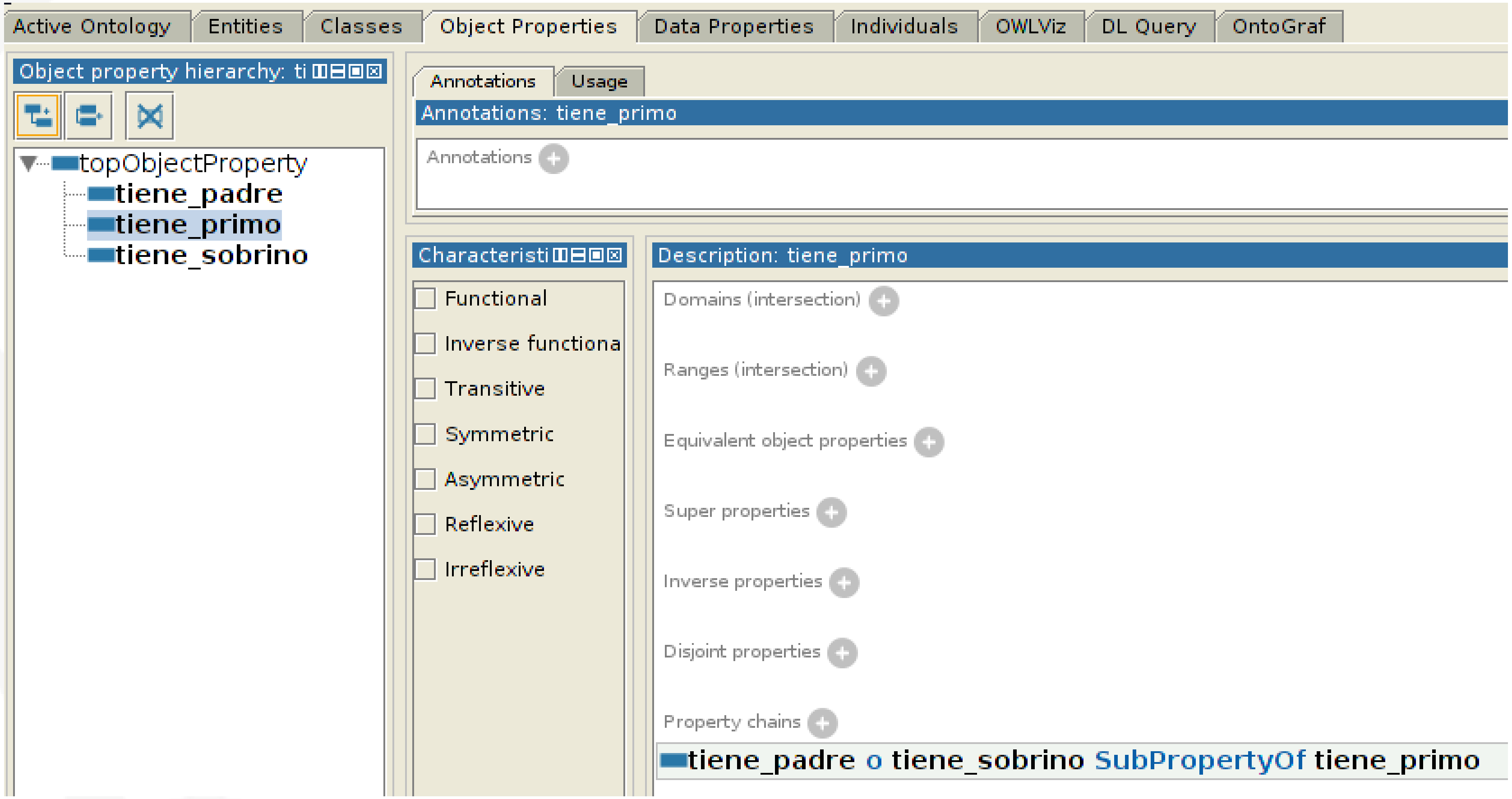
Members list
Members list (inferred)
Members list: Mi_retrovisor
Mi_retrovisor
Annotations
Usage
Annotations: Mi_retrovisor
Annotations
Description: Mi_retrovisor
Types
Recambio
Retrovisor
Same individuals
Retrovisor_de_mi_novia
Different individuals
retrovisor_de_pedro
Property assertions: Mi_retrovisor
Object property assertions
parte_de mi_coche
Data property assertions
tiene_precio 20
Negative object property assertions
parte_de coche_de_pedro
Negative data property assertions
tiene_precio 30

Some extra constructs

OWL oneOf


Class hierarchy
Class hierarchy (inferred)
Class hierarchy: FamiliaMikel
Thing
Familia
FamiliaMikel
Annotations
Usage
Annotations: FamiliaMikel
Annotations
Description: FamiliaMikel
Equivalent classes
{Iker , JuanRamon , Mikel}
Superclasses
Familia
Inherited anonymous classes
Members
Iker
JuanRamon
Mikel
Pedro

Role chains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Usage
Annotations: tiene_primo
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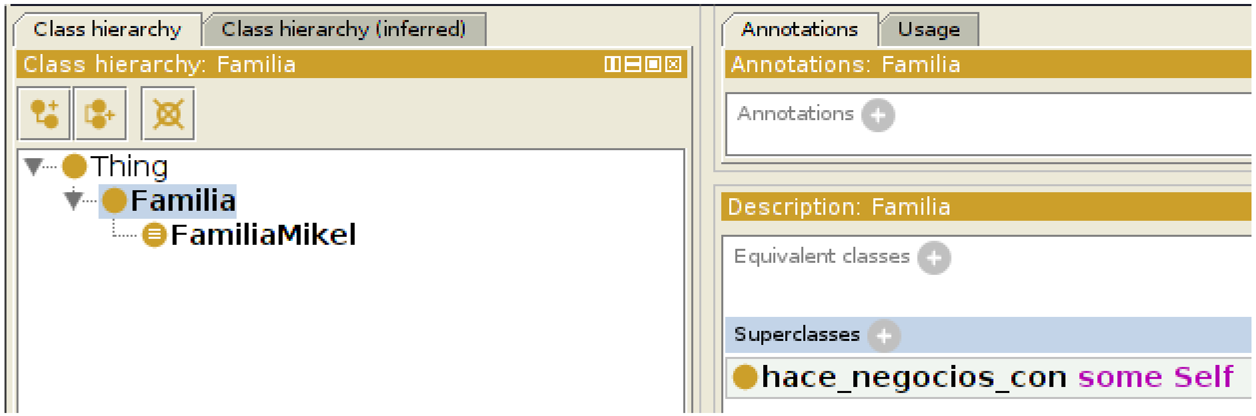
Inverse functiona
Transitive
Symmetric
Asymmetric
Reflexive
Irreflexive
Description: tiene_primo
Domains (intersection)
Ranges (intersection)
Equivalent object properties
Super properties
Inverse properties
Disjoint properties
Property chains
tiene_padre o tiene_sobrino SubPropertyOf tiene_primo

OWL Self


Class hierarchy
Class hierarchy (inferred)
Class hierarchy: Familia
Thing
Familia
FamiliaMikel
Annotations
Usage
Annotations: Familia
Annotations
Description: Familia
Equivalent classes
Superclasses
hace_negocios_con some Self

OWL keys

http://www.w3.org/TR/2009/REC-owl2-primer-20091027/#Keys

~ “datatype inverse functional”

numero_seguridad_social “7”^^xsd:integer
numero_seguridad_social “8”^^xsd:integer
numero_seguridad_social “7”^^xsd:integer

Reasoning

Reasoning

Reasoning is performed by using a reasoner: a reasoner infers the axioms implied by the axioms we have stated in the ontology

Thus, ther reasoner generates the *inferred* axioms from the *asserted* axioms

The reasoner makes *all* the implied axioms explicit, including the ones that would be missed by a human because of the complexity/size of the ontology

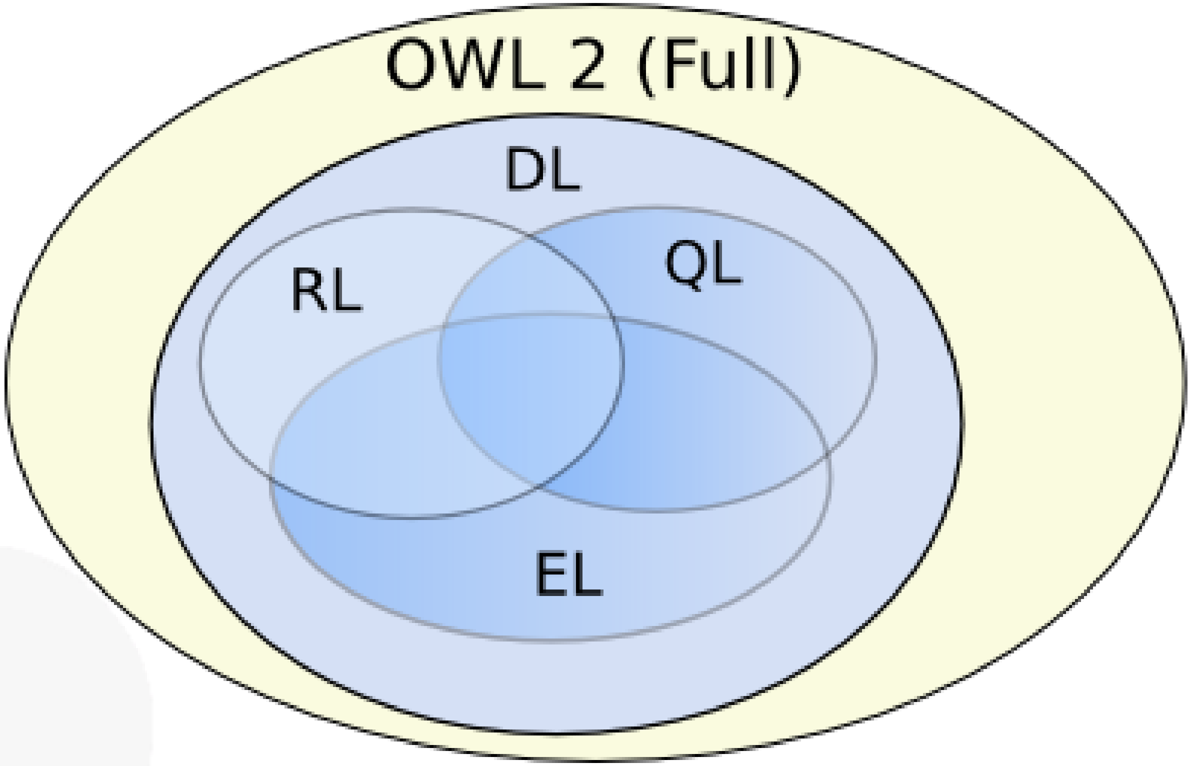
Therefore, a reasoner helps us deal with complex knowledge

OWL offers *sound and complete* reasoning if we don't use OWL full constructs (e.g. make an object property functional and transitive, …)

That is the theory. In practice there can be efficiency problems. Reasoners are improving fast and OWL 2 offers different profiles optimized for different kinds of reassoning

OWL profiles

http://www.w3.org/TR/owl2-profiles/



Reasoning can be used to:

Maintain a class hierarchy

Check consistency of the ontology

Clasify an entity against the ontology

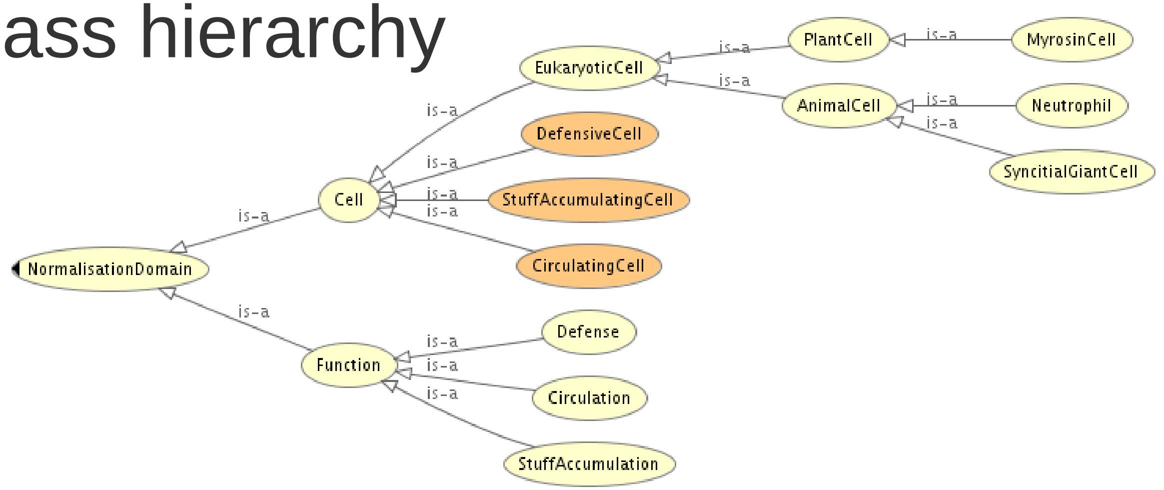
Make queries against the ontology

Use reasoning every time you change your ontology

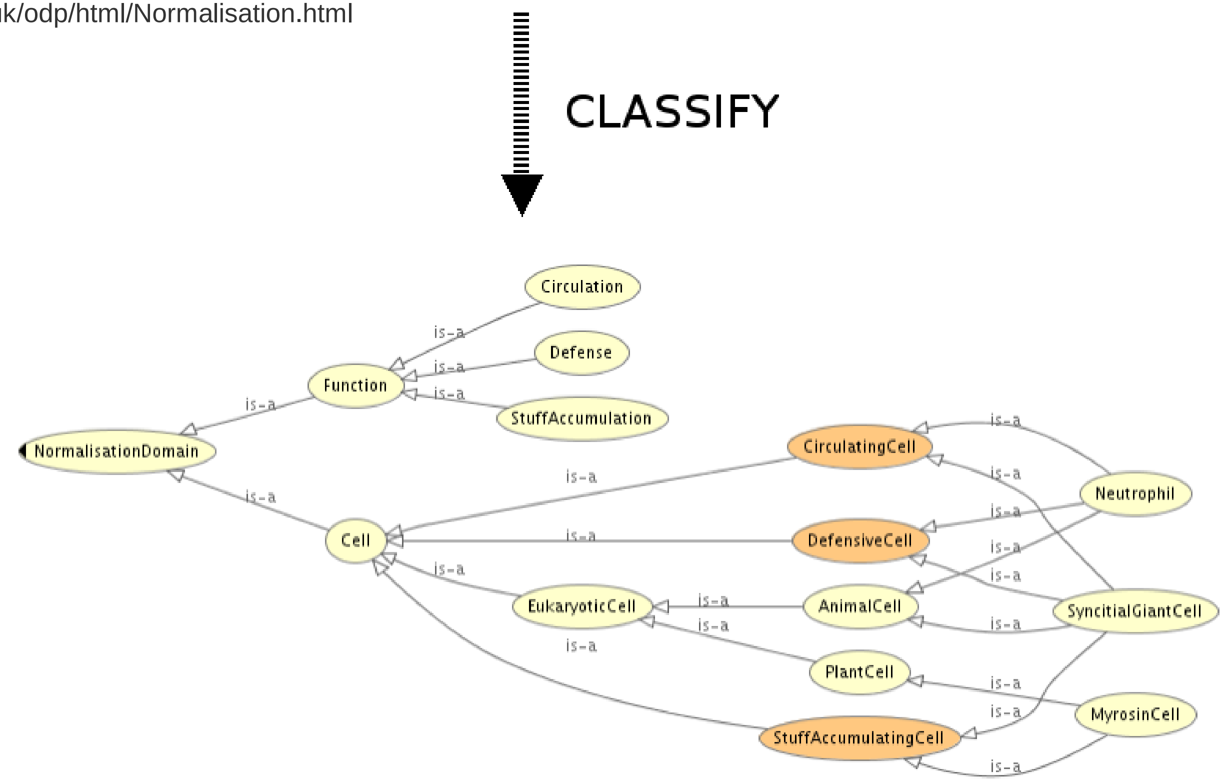
Be aware of OWA and lack of UNA

!!!

Maintain a class hierarchy



http://www.gong.manchester.ac.uk/odp/html/Normalisation.html



Check consistency of an ontology

Not satisfiable classes cannot have any individual (There is no individual that can satisfy the axioms)

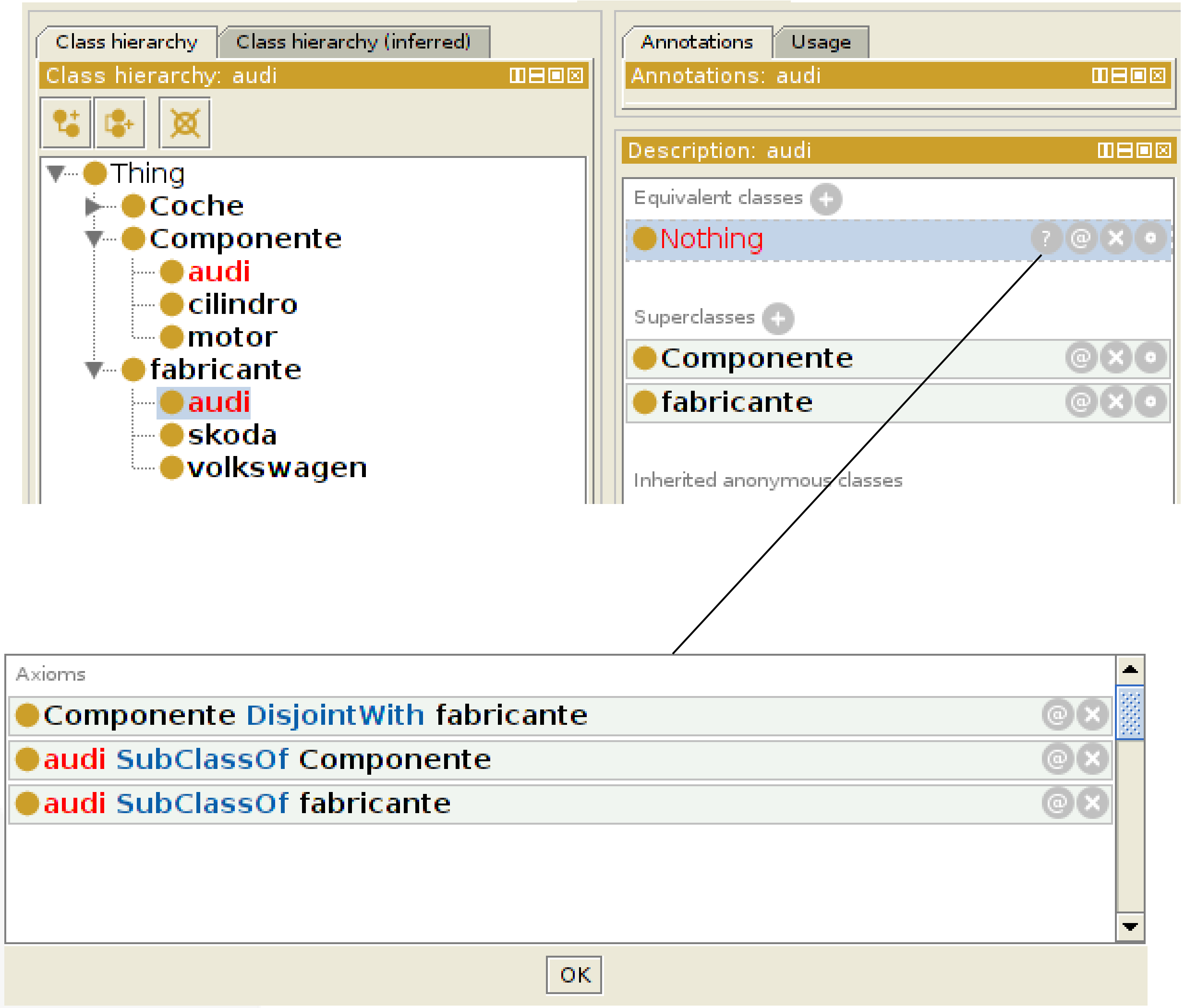
An ontology becomes *inconsistent* if we state that a not satisfiable class has an individual

In an inconsistent ontology, not satisfiable classes are subclasses of owl:Nothing

Automated reasoning cannot be performed in an inconsistent ontology

An inconsistent ontology usually means that we have modelled something wrong

Check consistency of an ontology



Classify new entities against the ontology

Individuals: types

Classes: subClassOf, equivalentTo

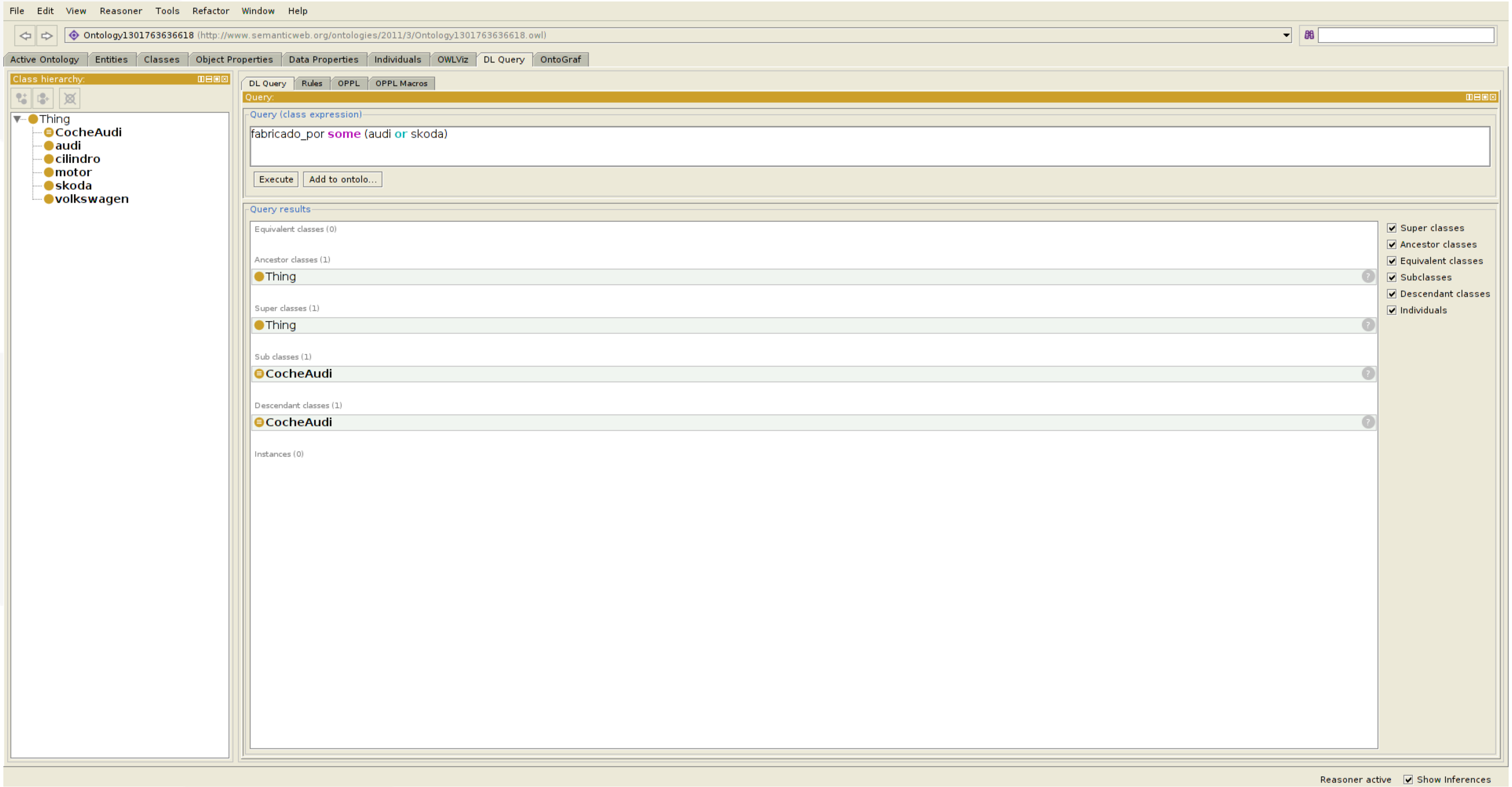
Queries against the ontology

A query is an anonymous class

We ask the reasoner how the entities of the ontology relate to such class (type, subclass, …)

Defined classes can also be regarded as queries

Reasoning


File Edit View Reasoner Tools Refactor Window Help
Ontology1301763636618 (http://www.semanticweb.org/ontologies/2011/3/Ontology1301763636618.owl)
Active Ontology
Entities
Classes
Object Properties
Data Properties
Individuals
OWLViz
DL Query
OntoGraf
Class hierarchy:
Thing
CocheAudi
audi
cilindro
motor
skoda
volkswagen
DL Query
Rules
OPPL
OPPL Macros
Query:
Query (class expression)
fabricado_por some (audi or skoda)
Execute
Add to ontolo...
Query results
Equivalent classes (0)
Ancestor classes (1)
Thing
Super classes (1)
Thing
Sub classes (1)
CocheAudi
Descendant classes (1)
CocheAudi
Instances (0)
Super classes
Ancestor classes
Equivalent classes
Subclasses
Descendant classes
Individuals
Reasoner active
Show Inferences

OWL tools

Ontology editors:

Protégé: http://protege.stanford.edu/
TopBraid composer:
    http://www.topquadrant.com/products/TB_Composer.html
NeOn toolkit: http://neon-toolkit.org

APIs:

OWL API: http://owlapi.sourceforge.net/

Reasoners:

Pellet: http://clarkparsia.com/pellet/
HermiT: http://hermit-reasoner.com/
FaCT++: http://code.google.com/p/factplusplus/
Racer: http://www.racer-systems.com/