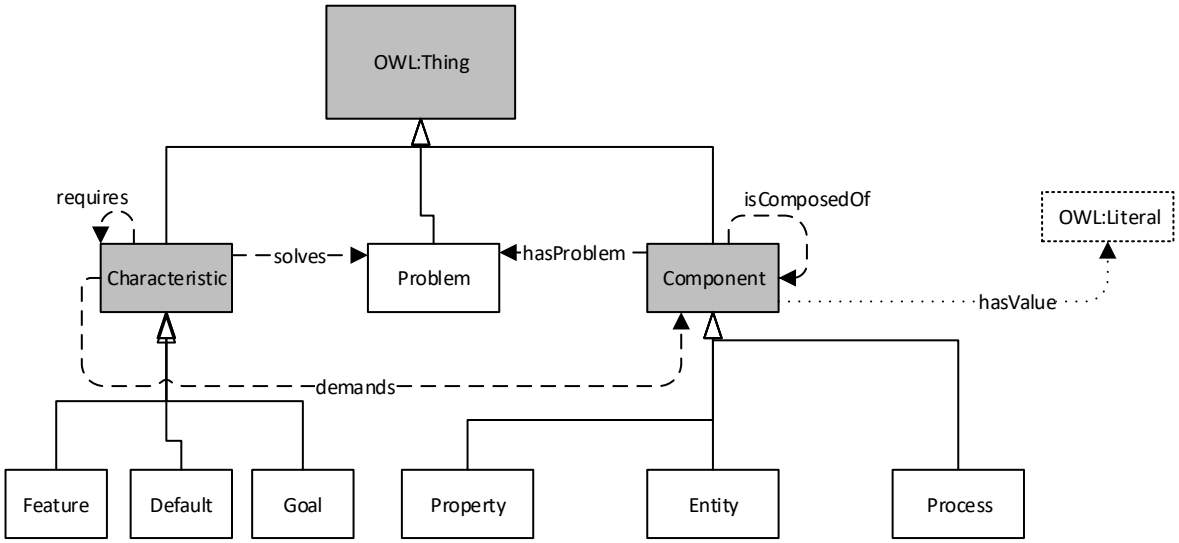
Contents

1 Classes

1.1 Upper Ontology



Class	Purpose
Characteristic	Model Characteristic
Feature	Model feature
Default	Model default Characteristic
Goal	Model goal
Component	Model description block
Property	Constants or Variables (e.g. basic types, composite types)
Entity	Structure (e.g. Program, File, Module, Package, Class)
Process	Continuous Behavior (e.g. Function, Method, Sequential instructions)
Problem	Problem raised by a Component

A class that contains no individual and is instantiable, i.e., does not contain annotations stating otherwise, is automatically instantiated by the DSL, which creates a single individual with the same name as the class (but starting with lower case).

1.1.1 Characteristic

A Characteristic represents features (attributes) and goals (desired results) of the model. These create an abstract layer above all Component classes.

Characteristic classes might be used to:

- Require or reject the instantiation of other Characteristics;

- Impose existential restrictions on Component individuals;
- Influence solution proposals, eliminating options that would generate errors by excess;
- Trigger SWRL rules, when instanced.

Characteristic classes can be instanced in two ways: either they are explicitly referenced in the DSL or they are required by other Characteristic classes. The Default Characteristic is special because it is used, even when not referenced, although it is not instanced in the ontology.

The DSL reports to the user which Characteristic classes are in use, every time the model is validated. If there is a non-solved requirement, it will display an error.

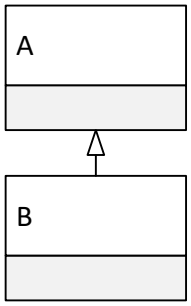
1.2 Required Individuals

Individuals must be static or required to be referenced in the DSL. Otherwise, an error will occur. If the individual is static, it will be instantiated when the model is created, being its references automatically allowed. Those individuals might be used on the left part of a relation. Individuals on the right part of a relation become allowed to be referenced in the left part of subsequent relations.

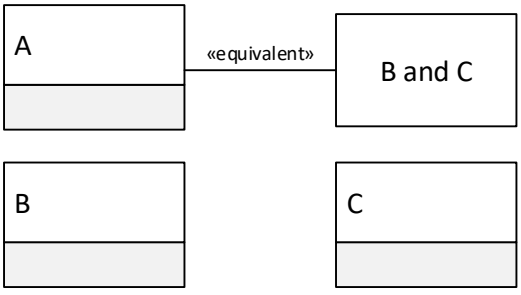
1.3 Theory

1.3.1 Transformation from UML Notation to OWL Notation

A class of an individual might be inferred from an equivalent class or from an SWRL rule.



Class: A
Class: B
SubClass Of: A



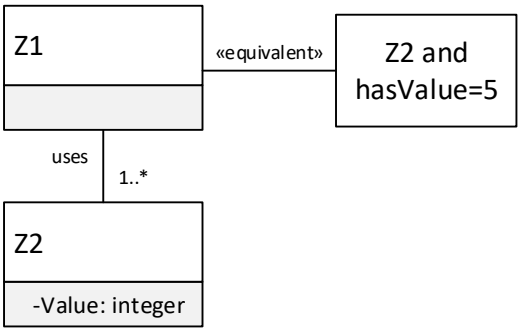
Class: A
Equivalent To: B and C
Class: B
Class: C

1.4 Examples

1.4.1 Example I

This example shows how to create classes equivalent to anonymous classes. It could be equally accomplished with an SWRL rule.

Z1 is equivalent to the anonymous class “Z2 and hasValue=5”. When z2 is referenced in the DSL, it must be assigned an integer. If that integer is equal to 5, z2 will inherit the restrictions of the Z1 class. This means that z2 must use some individual of Z2. However, if the integer is different from 5, z2 can’t use any individual, because the restrictions is not required.



Class: Z1
Equivalent To: Z2 and hasValue some {5}
SubClass Of: uses some Z2
Class: Z2
SubClass Of: hasValue some xsd:integer

2 Annotations

2.1 Implementation

2.1.1 Theory

The implementation stage is characterized by a strong relation between the DSL and user-defined external tools. Special annotations can be used to map ontological elements to implementation artefacts. Each annotation represents a different behavior as can be seen in the following table.

Annotation Property	Trigger Condition	Arguments	Assertion (Individual)	Assertion (Property)
ImplInd	instanced individual	individual*	tool,function [,annotProp]	-
ImplOP	instanced individual and OP	individual1*, individual2*	tool,function, property[,annotProp]**	tool:function [:annotProp]
ImplDP	instanced individual and DP	individual*, literal	tool,function, property[,annotProp]	tool:function [:annotProp]

*source of annotations (ImplArg or user-defined)
**assertion performed on first individual (relation's domain)

The annotation property is defined in the upper ontology. In the implementation stage, the DSL will look for trigger conditions to call a specific function of the provided tool. By default, the arguments sent to the tool are of type *ImplArg*, unless the user states otherwise when asserting the annotation. These arguments are taken from predefined ontological elements and sent to the tool's function. Each behavior is asserted in a certain element and contains a string with the tool name, function name and other parameters which depend on the chosen behavior.

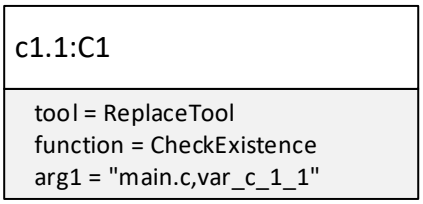
Before the implementation stage, a start function is called. After the stage, an end function is called.

2.1.2 Examples

2.1.2.1 Example I

This example shows how to perform a simple mapping from one individual of the model to the matching implementation artefact.

When the user runs the implementation stage, if c1.1 was referenced, the function "CheckExistence" of the tool "ReplaceTool" will be called with one argument, "main.c,var_c_1_1".



2.2 Modifiers

2.2.1 Theory

There are several modifiers which can be set via OWL annotations.

Annotation Property	Target Element	Meaning
NonInstantiable	OWL Class	Class won't generate individuals
DefaultValue	OWL Individual	Default value for the *hasValue* DP
ArraySize	OWL Individual	Number of individuals -1 to be generated
StaticIndividual	OWL Individual	Individual is a model entry point

3 Object Properties

3.1 Overview

The property must be required in order to be allowed in the DSL. Therefore, if the user does not create a restriction on any of the properties classes or declares the property as static, it cannot be referenced in the DSL.

3.2 Required Object Properties

Relations with object properties must be required, to be allowed in the DSL. Relations can be required by applying special restrictions on the classes of the individual which is on the left part of a relation. These restrictions must have a requirement behavior.

OP	Purpose	Domain	Range
demands	DSL Integration	Characteristic	Component
requires	DSL Integration	Characteristic	
solves	DSL Integration	Characteristic	Problem
uses	Normalize	Component	
isUsedBy	Normalize	Component	
isComposedOf	Normalize	Component	
isPartOf	Normalize	Component	

3.3 Component Relations

3.3.1 Theory

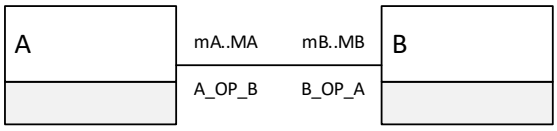
The user may create its own Object Properties in its own ontology without having to extend any existent property. However, to normalize knowledge across all domains, some Object Properties were created in the Upper Ontology: "uses", "isComposedOf" and the respective inverse properties.

Restriction Type	Behavior
some	Requirement
only	Restriction

value	Requirement
Self	Requirement
min	Requirement
max	Restriction
exactly	Requirement and Restriction

A `Descriptions` might contain unions (or logical operator) and intersections (and logical operator). Negation (not logical operator) is only allowed if nested inside a `primary`.

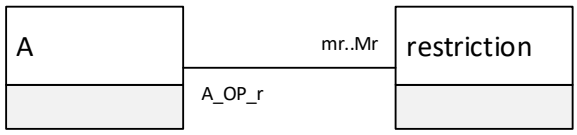
3.3.1.1 Transformation from UML Notation to OWL Notation



Class: A
SubClass Of: `restriction`
Class: B
SubClass Of: `restriction`

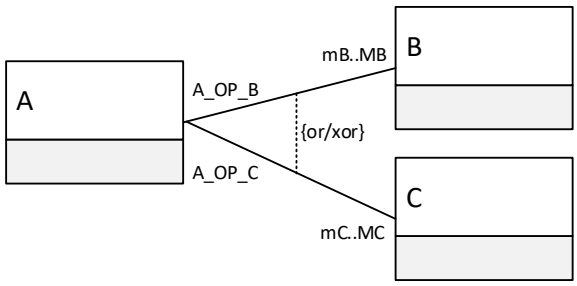
mA – minimum instances of A related with one instance of B
MA – maximum instances of A related with one instance of B
mB – minimum instances of B related with one instance of A
MB – maximum instances of B related with one instance of A
A_OP_B – object property pointing from A to B
B_OP_A – object property pointing from B to A
Multiplicity might also be represented as a number if the minimum and maximum values are equal

If A is connected to an anonymous class:



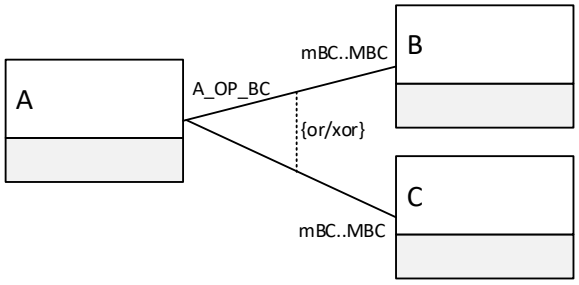
Class: A
SubClass Of: `restriction`

OR/XOR Relations:



Class: A
SubClass Of: `description` (or)
(xor requires particular analysis)
Class: B
Class: C

If (A_OP_B=A_OP_C) and (mb..MB=mc..MC):

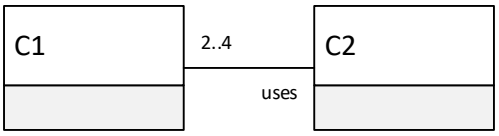


Class: A
SubClass Of: `description` (or)
(xor requires particular analysis)
Class: B
Class: C

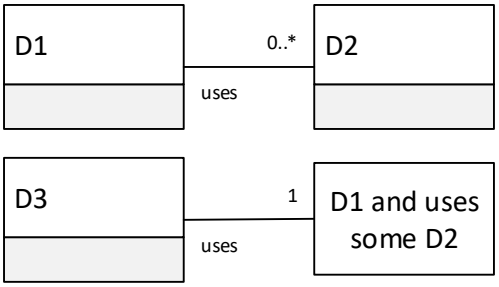
3.3.2 Examples

3.3.2.1 Example I

This example shows how to translate simple relations.



Class: C1
Class: C2
SubClass Of: (uses min 2 C1) and (uses max 4 C1)

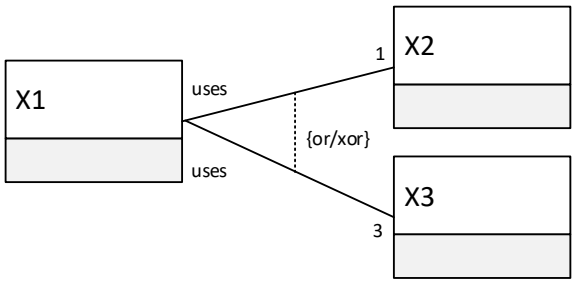


Class: D1
SubClass Of: uses min 0 D2
Class: D2
Class: D3
SubClass Of: uses exactly 1 (D1 and uses some D2)

3.3.2.2 Example II

This example shows a simple variability using different multiplicities.

OR/XOR Relations:

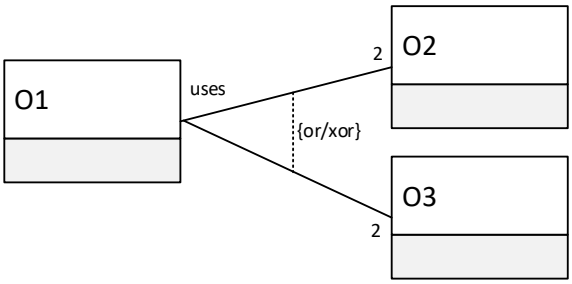


Class: X1
SubClass Of:
- (uses exactly 1 X2) or (uses exactly 3 X3)
- uses max 3 (X2 or X3) (if xor)

Class: X2
Class: X3

3.3.2.3 Example III

If (A_OP_B=A_OP_C) and (mb..MB=mc..MC):

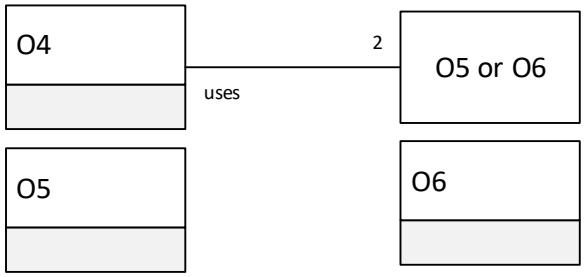


Class: O1
SubClass Of: (or)
- (uses exactly 2 O2) or (uses exactly 2 O3)

SubClass Of: (xor)
- (uses exactly 2 O2) or (uses exactly 2 O3)
- uses exactly 2 (O2 or O3)

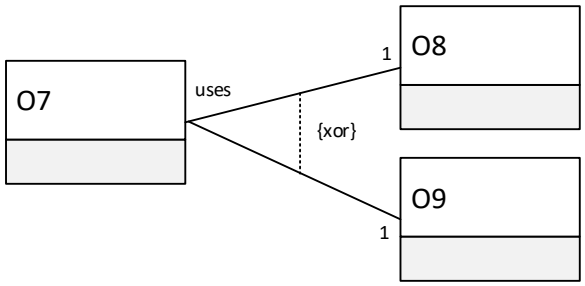
Class: O2
Class: O3

3.3.2.4 Example IV



Class: O4
SubClass Of: uses exactly 2 (O5 or O6)
Class: O5
Class: O6

3.3.2.5 Example V



Class: O7
SubClass Of: uses exactly 1 (O8 or O9)
Class: O8
Class: O9

3.4 Characteristic Relations

3.4.1 Theory

3.4.1.1 Existential Restrictions

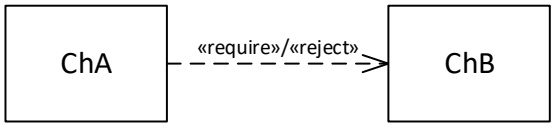
Any Characteristic can have existential restrictions. If a Characteristic requires the exclusive existence of one or another Characteristic, this mean that the user can only reference on of them.

The Characteristic class **Default** is used, even if it is not explicitly referenced. It is asserted in the Upper Ontology.

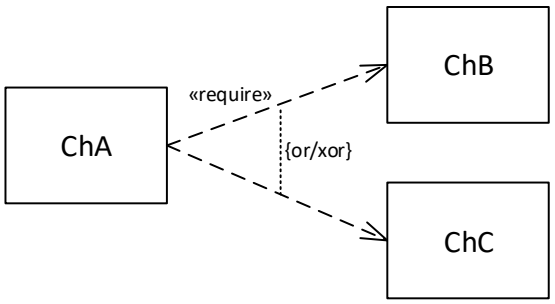
The following table shows the allowed restrictions which can be made using the Object Property “requires”.

Restriction Type	Cardinality	`primary`	Meaning
exactly	1	`classIRI`	Characteristic requires Characteristic
	0	`classIRI`	Characteristic rejects Characteristic
	1	`classIRI` (or `classIRI`)	Characteristic requires ∃! Characteristic (the others are rejected)
some	-	`classIRI` (or `classIRI`)	Characteristic requires ∃ Characteristic

3.4.1.2 Transformation from UML Notation to OWL Notation



Class: ChA (Characteristic)
SubClass Of: requires exactly 0/1 ChB
Class: ChB (Characteristic)



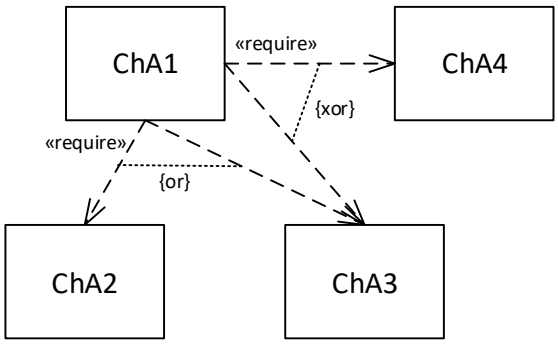
Class: ChA (Characteristic)
SubClass Of: requires (exactly 1)/some (ChB or ChC)
Class: ChB (Characteristic)
Class: ChC (Characteristic)

3.4.2 Examples

3.4.2.1 Example I

This example shows the interaction between Characteristic classes when using requirement relations with logical operators.

ChA1 requires (ChA2 or ChA3) and requires exclusively (ChA3 or ChA4). This example assumes that ChA1 is referenced. If the user references ChA2, there is still a variability to solve. If the user references ChA3, ChA2 can be referenced but ChA4 cannot, because of the exclusive requirement. If the user references ChA4, ChA3 cannot be referenced and ChA2 will automatically be used.



Class: ChA1 (Goal)
SubClass Of:
- requires some (ChA2 or ChA3)
- requires exactly 1 (ChA3 or ChA4)

Class: ChA2 (Feature)
Class: ChA3 (Feature)
Class: ChA4 (Feature)

3.5 Characteristic to Component Relations

3.5.1 Theory

Characteristics create an abstract layer above all Component classes. The restrictions imposed by Characteristic classes are useful to validate the model but also influence solution proposals, eliminating options that would generate errors by excess.

3.5.1.1 Restrictions

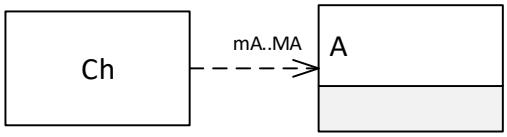
The following table shows which restriction can be made using the Object Property “demands”.

Restriction Type	Meaning	Behavior
some	Model contains some primary	Requirement
only	Model contains only primary	Restriction
value	Model contains individual	Requirement
Self	Not Supported	-

min	Model contains min n primary	Requirement
max	Model contains max n primary	Restriction
exactly	Model contains exactly n primary	Requirement and Restriction

A `Descriptions` might contain unions (or logical operator) and intersections (and logical operator). Negation (not logical operator) is only allowed if nested inside a `primary`.

3.5.1.2 Transformation from UML Notation to OWL Notation



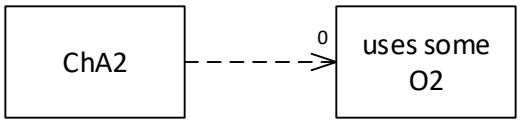
Class: A (Component)
Class: Ch (Characteristic)
SubClass Of: restriction

3.5.2 Examples

3.5.2.1 Example I

This example illustrates the effects of Characteristic imposed restrictions on the model's validation and solution proposals.

ChA2 requires the existence of zero individuals which belong to the anonymous class "uses some O2". If ChA2 is used and o1 is referenced the solution will contain only one proposal.



Class: Ch (Characteristic)
SubClass Of: demands max 0 (uses some O2)

4 Data Properties

4.1 Overview

OP	Purpose
hasValue	DSL Integration
hasReport	DSL Support (not instantiable)
hasError	DSL Integration
hasWarning	DSL Integration
hasInfo	DSL Integration

4.2 Required Data Properties

As with Object Properties, Data Properties must be required to be allowed in the DSL. Since the DSL only supports assignments with the "hasValue" Data Property, it is also the only one which needs to be required. This can be accomplished using any of the two allowed restrictions regarding "hasValue".

4.3 Reports

4.3.1 Theory

Reports are intuitive and descriptive messages for the DSL User, for when a certain incongruence occurs or a specific combination of components raises a warning or a special information for the user.

These are static or dynamically created using SWRL rules. There are 3 data properties *hasError*, *hasWarning* and *hasInfo* which can be used to generate reports. Any datatype is allowed.

4.3.2 Examples

4.3.2.1 Example I

This example shows how to create a report, namely, an information report, using SWRL rules.

For each individual of R1 and R2, the SWRL rule will create an information report that sums the values assigned to both individuals through the "hasValue" Data Property. The resulting report will be attached to the evaluated individual of R1 using the "hasInfo" Data Property.

R1	R2
-Value: integer	-Value: integer

If r1 ∈ R1, r2 ∈ R2, r1 hasValue v1, r2 hasValue v2 **then** r1 hasInfo "r1 + r2 = ?"

SWRL Rule: R1(?r1) ^ R2(?r2) ^ hasValue(?r1, ?v1) ^ hasValue(?r2, ?v2) ^ swrlb:add(?v3, ?v1, ?v2) ^ swrlb:stringConcat(?s, "r1 + r2 = ", ?v3) -> hasInfo(?r1, ?s)

4.4 Value and user-defined data properties

4.4.1 Theory

4.4.1.1 Transformation from UML Notation to OWL Notation

A
-AttributeName: TypeName[*] {constraint}

User-defined Data Property
AttributeName: String
TypeName: [xsd:] RDF Datatype
(omitted if contained in constraint)
[*]: Multiplicity. Options:
- Omitted if the multiplicity is 1
- [<lower-bound> '..' <upper-bound>]

constraint: literal constraint

hasValue Data Property
AttributeName: Value
TypeName: [xsd:] RDF Datatype
(omitted if contained in constraint)
[*]: Multiplicity. Options:
- Omitted if the multiplicity is 1
- [0..1] if value is not mandatory

constraint: literal constraint

a:A
default = defaultValue arraySize = arraySizeValue

OWL 2 Manchester Syntax Transformation

Class: A
SubClass Of: `description`

Class: A
SubClass Of: hasValue some/only dataPrimary

dataRange ::= dataConjunction 'or' dataConjunction { 'or' dataConjunction } | dataConjunction
dataConjunction ::= dataPrimary 'and' dataPrimary { 'and' dataPrimary } | dataPrimary
dataPrimary ::= ['not'] dataAtomic
dataAtomic ::= Datatype | '{' literalList '}' | datatypeRestriction | '(' dataRange ')'
datatypeRestriction ::= Datatype '[' facet restrictionValue { ',' facet restrictionValue } ']'
facet ::= 'length' | 'minLength' | 'maxLength' | 'pattern' | 'langRange' | '<=' | '<' | '>=' | '>'
restrictionValue ::= literal

Individual: a
Annotations:
- *hasDefaultValue* defaultValue
- *isArray* arraySizeValue (xsd:integer)

4.4.1.2 Notes

There is only one predefined Component data property, *hasValue*, which is defined in the upper ontology. The property is functional, which means that it can only have one value per individual. It can

be used to validate the model and/or take part in code generation. The restrictions regarding this property must be of type *some* or *only*. Some logical operators are not allowed in the external part of the restricting expression: Negation and the *OR* logical operator.

These expressions are not allowed because they contain illegal uses of *or* and *not* keywords:

- (not (hasValue some xsd:float))
- (hasValue some xsd:integer) or (hasValue some xsd:float)
- (hasValue some xsd:integer) or (not (hasValue some xsd:float))

The same expressions can be rewritten to abide by the rules:

- hasValue only not xsd:float
- hasValue some xsd:integer or xsd:float
- hasValue only not xsd:float

While dealing with data properties, both *some* and *only* will act as requirements, so that a specific individual can be assigned a value in the DSL. The following table shows the effects of data property class restrictions:

Purpose	Restriction	Reasoner Effect	DSL Effect
The individual must be assigned some value	hasValue some dataPrimary	The dataPrimary will be tested if the relation is instantiated	The assignment is compulsory. If an individual is instantiated and it is not assigned, an error is thrown.
The individual can be assigned a value	hasValue only dataPrimary	The dataPrimary will be tested if the relation is instantiated	The assignment is allowed.

User-defined data properties are only evaluated by the reasoner and cannot be assigned in the DSL. Although these have a reasoner effect and can be used to validate the model, the DSL won't evaluate the corresponding class restrictions and the data properties may only be used for code generation if they are constant or rule-defined.

4.4.1.3 Datatype transformations

Input RDF Datatype (default)	DSL	Output RDF Datatype
xsd:boolean	BOOL	xsd:boolean
xsd:float	FLOAT	xsd:double
xsd:double		
xsd:integer	INT	xsd:integer
other	STRING	xsd:string

4.4.2 Examples

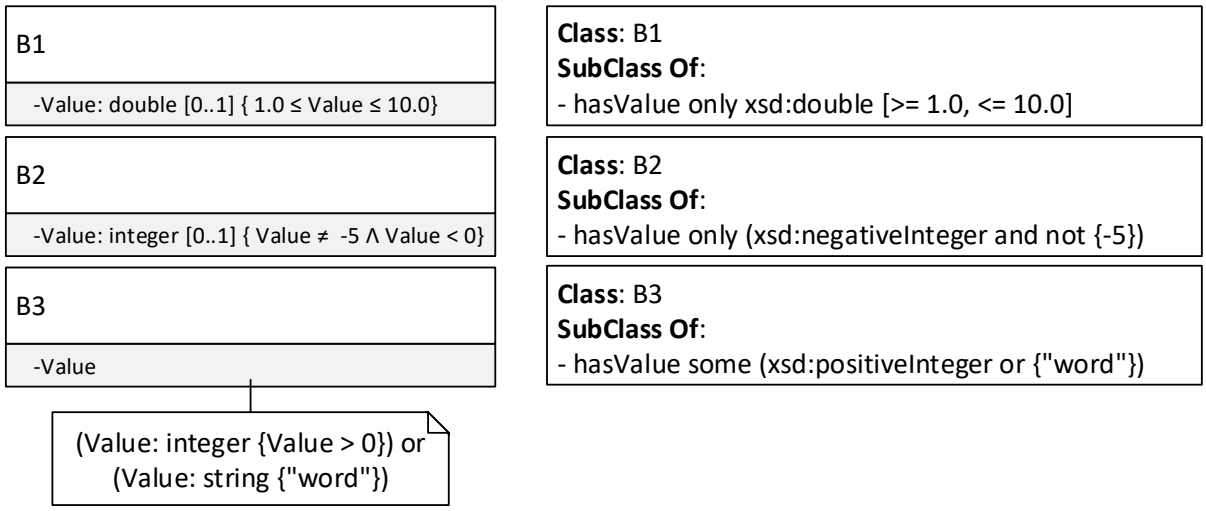
4.4.2.1 Example I

This example shows how to assert simple data property restrictions.

The class B1 is composed of individuals which may be connected to a literal, hence the multiplicity [0..1]. That literal must be a value of type *xsd:double*, ranging from 1.0 to 10.0. The keyword "only" is used because the relation is not required.

The second class has a similar constraint except that it uses negation, which can be transformed to OWL 2 using the keyword “not”. The constraint datatype is *xsd:integer* but, since the value must be negative, that can be represented in OWL 2 with the datatype *xsd:negativeInteger*.

The third class’s individuals may be connected to a positive integer or a string equal to “word”. The connection is not optional though. Since the datatype is not fixed, it must be represented as a constraint.

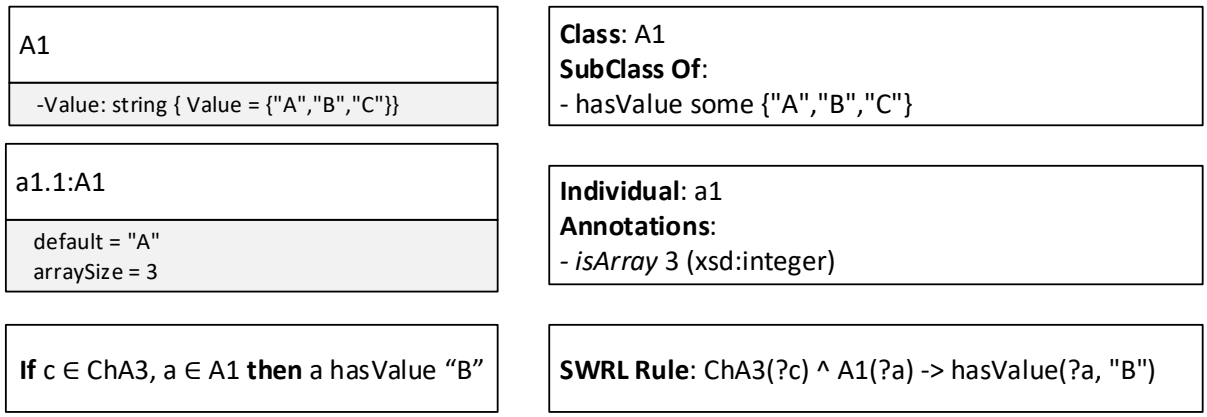


4.4.2.2 Example II

Arrays can also be used in conjunction with default values. If a certain individual represents an array and has a default value, each element will share that same value. This example also implements a rule that relates the use of a Characteristic with a value assignment.

A1 uses an enumeration constraint, containing string elements. Its only individual, a1.1 is an array. The DSL will search for the last number in the individual’s name which will act as the initial index. The remaining elements will be named after the first, with incremental indexing.

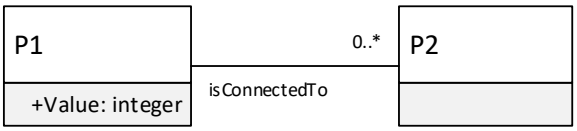
When ChA3 is used, all individuals of class A1 are assigned with a value, “B”.



4.4.2.3 Example III

The purpose of this example is to integrate rules in the process of creating a data property, when the trigger is another relation. This establishes a condition to check whether the user should be given the option of manually creating the assignment.

Assume that a model is composed of two classes: P1 and P2. Every individual of P1 must be connected to a literal, of type *xsd:integer*, through the *hasValue* data property. If that individual is connected to an individual of P2, the literal's value is 30. Otherwise, the literal must be manually assigned, being 50 its default value.



Class: P1
SubClass Of:
- hasValue some xsd:integer
- isConnectedTo min 0 P2
Class: P2

If a ∈ P1, b ∈ P2, a isConnectedTo b
then a hasValue 30

P1(?a) ^ P2(?b) ^ isConnectedTo(?a, ?b) -> hasValue(?a, 30)

Individual: p1 (P1)
Annotations:
- hasDefaultValue: 50 [xsd:integer]
Individual: p2 (P2)

5 SWRL

5.1 Characteristic

5.1.1 Theory

Some inferences cannot be expressed in OWL. SWRL should be used in those cases.