

Methods and Tools for Management Information Systems

Lecture 5

8. Juni 2009



Web Ontology Language (OWL)

- Intended to be used when the information contained in documents needs to be processed by *applications* rather than humans
- Explicitly represents the *meaning* of terms in vocabularies and the relationships between those terms
- Representation of terms and their interrelationships is called an *ontology*
- Offers more facilities for expressing meaning and semantics than XML, RDF and RDF Schema



- OWL is part of the growing stack of W3C recommendations related to the *Semantic Web*:
 - XML provides a surface syntax for structured documents, but imposes no semantic constraints on the meaning of these documents
 - XML Schema is a language for restricting the structure of XML documents and also extends XML with datatypes
 - RDF is a datamodel for objects (i. e. resources) and relations between them, provides a simple semantics for this datamodel, and these datamodels can be represented in an XML syntax
 - RDF Schema is a vocabulary for describing properties and classes of RDF resources, with a semantics for generalization-hierarchies of such properties and classes



- OWL adds more vocabulary for describing properties and classes:
 - Relations between classes (e. g. disjointness)
 - Cardinality (e. g. *exactly one*)
 - Equality
 - Richer typing of properties
 - Characteristics of properties (e. g. symmetry)
 - Enumerated classes



- OWL provides three increasingly expressive sublanguages:
 - *OWL Lite* supports classification hierarchies and simple constraints
 - *OWL DL* allows for maximum expressiveness while retaining *computational completeness* (all conclusions are guaranteed to be computable) and *decidability* (all computations will finish in finite time)
 - *OWL Full* allows for maximum expressiveness and the syntactic freedom of RDF with no computational guarantees
- Each of these sublanguages is an extension of its simpler predecessor:
 - Every legal OWL Lite ontology is a legal OWL DL ontology
 - Every legal OWL DL ontology is a legal OWL Full ontology
 - Every valid OWL Lite conclusion is a valid OWL DL conclusion
 - Every valid OWL DL conclusion is a valid OWL Full conclusion



■ OWL Lite Overview:

RDF Schema Features:

- ⇒ *Class (Thing, Nothing)*
- ⇒ *rdfs:subClassOf*
- ⇒ *rdf:Property*
- ⇒ *rdfs:subPropertyOf*
- ⇒ *rdfs:domain*
- ⇒ *rdfs:range*
- ⇒ *Individual*

Property Characteristics:

- ⇒ *ObjectProperty*
- ⇒ *inverseOf*
- ⇒ *SymmetricProperty*
- ⇒ *InverseFunctionalProperty*

(In)Equality:

- ⇒ *equivalentClass*
- ⇒ *equivalentProperty*
- ⇒ *sameAs*
- ⇒ *differentFrom*
- ⇒ *AllDifferent*
- ⇒ *distinctMembers*

- ⇒ *DatatypeProperty*
- ⇒ *TransitiveProperty*
- ⇒ *FunctionalProperty*



■ OWL Lite Overview (2):

Property Restrictions:

- ⇒ *Restriction*
- ⇒ *onProperty*
- ⇒ *allValuesFrom*
- ⇒ *someValuesFrom*

Header Information:

- ⇒ *Ontology*
- ⇒ *imports*

Restricted Cardinality:

- ⇒ *minCardinality*
- ⇒ *maxCardinality*
- ⇒ *cardinality*

Class Intersection:

- ⇒ *intersectionOf*

Datatypes:

- ⇒ *xsd datatypes*



■ OWL Lite Overview (3):

Versioning:

- ⇒ *versionInfo*
- ⇒ *priorVersion*
- ⇒ *backwardCompatibleWith*
- ⇒ *incompatibleWith*
- ⇒ *DeprecatedClass*
- ⇒ *DeprecatedProperty*

Annotation Properties:

- ⇒ *rdfs:label*
- ⇒ *rdfs:comment*
- ⇒ *rdfs:seeAlso*
- ⇒ *rdfs:isDefinedBy*
- ⇒ *AnnotationProperty*
- ⇒ *OntologyProperty*



■ OWL DL and Full Overview:

Class Axioms:

- ⇒ *oneOf*
- ⇒ *disjointWith*
- ⇒ *equivalentClass*
(applied to class expressions)
- ⇒ *rdfs:subClassOf*
(applied to class expressions)

Arbitrary Cardinality:

- ⇒ *minCardinality*
- ⇒ *maxCardinality*
- ⇒ *cardinality*

Boolean Combinations of Class Expressions:

- ⇒ *unionOf*
- ⇒ *complementOf*
- ⇒ *intersectionOf*

Filler Information::

- ⇒ *hasValue*



Class:

- ⇒ A group of individuals that belong together because they share some properties
- ⇒ Classes can be organized in a specialization hierarchy using `subClassOf`
- ⇒ There is a built-in most general class named `Thing` that is the class of all individuals and is a superclass of all OWL classes
- ⇒ There is also a built-in most specific class named `Nothing` that is the class that has no instances and a subclass of all OWL classes

Example:

```
<owl:Class rdf:ID="Winery"/>  
<owl:Class rdf:ID="Region"/>  
<owl:Class rdf:ID="ConsumableThing"/>
```



`rdfs:subClassOf`:

- ⇒ Class hierarchies may be created by making one or more statements that a class is a subclass of another class
- ⇒ May only be used in conjunction with single class names (as opposed to OWL DL and Full)

Example:

```
<owl:Class rdf:ID="Wine">  
  <rdfs:subClassOf rdf:resource="&food;PotableLiquid"/>  
  <rdfs:label xml:lang="fr">vin</rdfs:label>  
</owl:Class>  
<owl:Class rdf:ID="Pasta">  
  <rdfs:subClassOf rdf:resource="#EdibleThing"/>  
</owl:Class>
```



rdf:Property:

- ⇒ Properties can be used to state relationships between individuals (`owl:ObjectProperty`) or from individuals to XSD data values and RDF literals (`owl:DatatypeProperty`)
- ⇒ `owl:ObjectProperty` and `owl:DatatypeProperty` are subclasses of the RDF class `rdf:Property`

Example:

```
<owl:ObjectProperty rdf:ID="madeFromGrape">  
  <rdfs:domain rdf:resource="#Wine"/>  
  <rdfs:range rdf:resource="#WineGrape"/>  
</owl:ObjectProperty>
```



`rdfs:subPropertyOf`:

- ⇒ Property hierarchies may be created by making one or more statements that a property is a subproperty of one or more other properties

Example:

```
<owl:ObjectProperty rdf:ID="hasWineDescriptor">  
  <rdfs:domain rdf:resource="#Wine" />  
  <rdfs:range rdf:resource="#WineDescriptor"/>  
</owl:ObjectProperty>
```

```
<owl:ObjectProperty rdf:ID="hasColor">  
  <rdfs:subPropertyOf rdf:resource="#hasWineDescriptor"/>  
  <rdfs:range rdf:resource="#WineColor"/>  
</owl:ObjectProperty>
```



`rdfs:domain:`

- ⇒ A domain of a property limits the individuals to which the property can be applied

Example:

```
<owl:ObjectProperty rdf:ID="madeFromGrape">  
  <rdfs:domain rdf:resource="#Wine"/>  
  <rdfs:range rdf:resource="#WineGrape"/>  
</owl:ObjectProperty>
```



rdfs:range:

- ⇒ The range of a property limits the individuals that the property may have as its value

Example:

```
<owl:ObjectProperty rdf:ID="madeFromGrape">  
  <rdfs:domain rdf:resource="#Wine"/>  
  <rdfs:range rdf:resource="#WineGrape"/>  
</owl:ObjectProperty>
```



Individual:

- ⇒ Individuals are instances of classes, and properties may be used to relate one individual to another

Example:

```
<owl:Thing rdf:ID="CentralCoastRegion"/>
<owl:Thing rdf:about="#CentralCoastRegion">
  <rdf:type rdf:resource="#Region"/>
</owl:Thing>

<WineGrape rdf:ID="CabernetSauvignonGrape"/>
```



equivalentClass:

- ⇒ Two classes may be stated to be equivalent
- ⇒ May only be used in conjunction with single class names (as opposed to OWL DL and Full)
- ⇒ Equivalent classes have the same instances
- ⇒ Equality can be used to create synonymous classes

Example:

```
<owl:Class rdf:ID="Wine">  
  <owl:equivalentClass rdf:resource="&vin;Wine"/>  
</owl:Class>
```



equivalentProperty:

- ⇒ Two properties may be stated to be equivalent
- ⇒ Equivalent properties have the same range and domain
- ⇒ Equality can be used to create synonymous properties

Example:

```
<rdf:Property rdf:ID="weight">  
  <owl:equivalentProperty rdf:resource="&ex;weight"/>  
</rdf:Property>
```



sameAs:

- ⇒ Two individuals may be stated to be the same
- ⇒ These constructs may be used to create a number of different names that refer to the same individual

Example:

```
<Wine rdf:ID="MikesFavoriteWine">  
  <owl:sameAs rdf:resource="#TexasWhite"/>  
</Wine>
```



differentFrom:

⇒ An individual may be stated to be different from other individuals

Example:

```
<WineSugar rdf:ID="Dry"/>
```

```
<WineSugar rdf:ID="Sweet">
```

```
  <owl:differentFrom rdf:resource="#Dry"/>
```

```
</WineSugar>
```



AllDifferent:

- ⇒ A number of individuals may be stated to be mutually distinct in one statement
- ⇒ Particularly useful when there are sets of distinct objects and when modelers are interested in enforcing the unique names assumption within those sets of objects

Example:

```
<owl:AllDifferent>
  <owl:distinctMembers rdf:parseType="Collection">
    <vin:WineColor rdf:about="#Red"/>
    <vin:WineColor rdf:about="#White"/>
  </owl:distinctMembers>
</owl:AllDifferent>
```



distinctMembers:

- ⇒ All members of a list are distinct and pairwise disjoint
- ⇒ Can only be used in combination with `owl:AllDifferent`

Example:

```
<owl:AllDifferent>  
  <owl:distinctMembers rdf:parseType="Collection">  
    <vin:WineColor rdf:about="#Red"/>  
    <vin:WineColor rdf:about="#White"/>  
  </owl:distinctMembers>  
</owl:AllDifferent>
```



inverseOf:

⇒ One property may be stated to be the inverse of another property:

$$P_1(x, y) \Rightarrow P_2(y, x)$$

Example:

```
<owl:ObjectProperty rdf:ID="hasMaker">  
  <rdf:type rdf:resource="#owl:FunctionalProperty"/>  
</owl:ObjectProperty>
```

```
<owl:ObjectProperty rdf:ID="producesWine">  
  <owl:inverseOf rdf:resource="#hasMaker"/>  
</owl:ObjectProperty>
```



TransitiveProperty:

⇒ Properties may be stated to be transitive:

$$P(x, y) \wedge P(y, z) \Rightarrow P(x, z)$$

Example:

```
<owl:ObjectProperty rdf:ID="locatedIn">  
  <rdf:type rdf:resource="&owl;TransitiveProperty"/>  
  <rdfs:domain rdf:resource="&owl;Thing"/>  
  <rdfs:range rdf:resource="#Region"/>  
</owl:ObjectProperty>
```



SymmetricProperty:

⇒ Properties may be stated to be symmetric:

$$P(x, y) \Rightarrow P(y, x)$$

Example:

```
<owl:ObjectProperty rdf:ID="adjacentRegion">  
  <rdf:type rdf:resource="&owl;SymmetricProperty"/>  
  <rdfs:domain rdf:resource="#Region"/>  
  <rdfs:range rdf:resource="#Region"/>  
</owl:ObjectProperty>
```



FunctionalProperty:

- ⇒ If a property is a `owl:FunctionalProperty`, then it has no more than one value for each individual (unique property):

$$P(x, y) \wedge P(x, z) \Rightarrow y = z$$

- ⇒ Shorthand for stating that the property's minimum cardinality is zero and its maximum cardinality is 1

Example:

```
<owl:ObjectProperty rdf:ID="hasVintageYear">  
  <rdf:type rdf:resource="#owl:FunctionalProperty"/>  
  <rdfs:domain rdf:resource="#Vintage"/>  
  <rdfs:range rdf:resource="#VintageYear"/>  
</owl:ObjectProperty>
```



InverseFunctionalProperty:

⇒ If a property is inverse functional then the inverse of the property is functional (unambiguous property):

$$P(y, x) \wedge P(z, x) \Rightarrow y = z$$

Example:

```
<owl:ObjectProperty rdf:ID="producesWine">  
  <rdf:type rdf:resource="&owl;InverseFunctionalProperty"/>  
  <owl:inverseOf rdf:resource="#hasMaker"/>  
</owl:ObjectProperty>
```



Restriction:

- ⇒ For placing restrictions on the usage of properties by class instances
- ⇒ Applies to its containing class definition only

Example:

```
<owl:Class rdf:ID="Wine">
  <rdfs:subClassOf rdf:resource="&food;PotableLiquid"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <!-- .... -->
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```



onProperty:

⇒ Indicates the restricted property

Example:

```
<owl:Class rdf:ID="Wine">
  <rdfs:subClassOf rdf:resource="&food;PotableLiquid"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasMaker"/>
      <!-- .... -->
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```



allValuesFrom:

- ⇒ Stated on a property with respect to a class (local range restriction)
- ⇒ Values of the property are all members of the class indicated

Example:

```
<owl:Class rdf:ID="Wine">
  <rdfs:subClassOf rdf:resource="&food;PotableLiquid"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasMaker"/>
      <owl:allValuesFrom rdf:resource="#Winery"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```



someValuesFrom:

- ⇒ Stated on a property with respect to a class (local range restriction)
- ⇒ At least one value for that property is of a certain type

Example:

```
<owl:Class rdf:ID="Wine">
  <rdfs:subClassOf rdf:resource="#food;PotableLiquid"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasMaker"/>
      <owl:someValuesFrom rdf:resource="#Winery"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```



minCardinality:

- ⇒ Stated on a property with respect to a particular class
- ⇒ Permits the specification of the minimum number of elements in a relation (0 or 1)

Example:

```
<owl:Restriction>  
  <owl:onProperty rdf:resource="#hasMother"/>  
  <owl:minCardinality rdf:datatype="&xsd;nonNegativeInteger">1  
    </owl:minCardinality>  
</owl:Restriction>
```



maxCardinality:

- ⇒ Stated on a property with respect to a particular class
- ⇒ Permits the specification of the maximum number of elements in a relation (0 or 1)

Example:

```
<owl:Restriction>  
  <owl:onProperty rdf:resource="#hasMother"/>  
  <owl:maxCardinality rdf:datatype="&xsd;nonNegativeInteger">1  
    </owl:maxCardinality>  
</owl:Restriction>
```



cardinality:

- ⇒ Permits the specification of exactly the number of elements in a relation (0 or 1)

Example:

```
<owl:Class rdf:ID="Vintage">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasVintageYear"/>
      <owl:cardinality rdf:datatype="&xsd;nonNegativeInteger">1
    </owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```



Ontology:

- ⇒ An ontology is a resource and may be described using properties
- ⇒ If the value of `rdf:about` is empty, the name of the ontology is the base URI of the `owl:Ontology` element

Example:

```
<owl:Ontology rdf:about="">
  <owl:versionInfo>
    v 1.17 2003/02/26 12:56:51 mdean
  </owl:versionInfo>
  <rdfs:comment>
    Comments are used to annotate ontologies.
  </rdfs:comment>
</owl:Ontology>
```



imports:

- ⇒ References another OWL ontology containing definitions, whose meaning is considered to be part of the meaning of the importing ontology
- ⇒ `owl:imports` is a property with the class `owl:Ontology` as its domain and range
- ⇒ Imports are transitive

Example:

```
<owl:Ontology rdf:about="">  
  <!-- .... -->  
  <owl:imports rdf:resource="http://www.example.org/foo"/>  
</owl:Ontology>
```



intersectionOf:

⇒ Allows for intersections of named classes and restrictions

Example:

```
<owl:Class rdf:ID="WhiteWine">
  <owl:intersectionOf rdf:parseType="Collection">
    <owl:Class rdf:about="#Wine"/>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasColor"/>
      <owl:hasValue rdf:resource="#White"/>
    </owl:Restriction>
  </owl:intersectionOf>
</owl:Class>
```



xsd datatypes:

⇒ OWL uses most of the built-in XML Schema datatypes

Example:

```
<owl:Class rdf:ID="VintageYear"/>  
  
<owl:DatatypeProperty rdf:ID="yearValue">  
  <rdfs:domain rdf:resource="#VintageYear"/>  
  <rdfs:range rdf:resource="&xsd;positiveInteger"/>  
</owl:DatatypeProperty>
```



versionInfo:

- ⇒ A string giving information about the version of the corresponding OWL construct

Example:

```
<owl:Ontology rdf:about="">  
  <owl:versionInfo>  
    v 1.17 2003/02/26 12:56:51 mdean  
  </owl:versionInfo>  
</owl:Ontology>
```



priorVersion:

- ⇒ Reference to another ontology that identifies the specified ontology as a prior version of the containing ontology

Example:

```
<owl:Ontology rdf:about="">  
  <owl:priorVersion rdf:resource="http://www.example.org/old"/>  
</owl:Ontology>
```



backwardCompatibleWith:

- ⇒ Reference to another ontology that identifies the specified ontology as a prior version of the containing ontology, and further indicates that it is backward compatible with it

Example:

```
<owl:Ontology rdf:about="">  
  <owl:backwardCompatibleWith  
    rdf:resource="http://www.example.org/old"/>  
</owl:Ontology>
```



incompatibleWith:

- ⇒ Reference to another ontology that identifies the specified ontology as a prior version of the containing ontology, and further indicates that is not backward compatible with it

Example:

```
<owl:Ontology rdf:about="">  
  <owl:incompatibleWith  
    rdf:resource="http://www.example.org/old"/>  
</owl:Ontology>
```



DeprecatedClass:

- ⇒ Class is preserved for backward-compatibility purposes, but may be phased out in the future

Example:

```
<owl:DeprecatedClass rdf:ID="Car">  
  <rdfs:comment>Automobile is now preferred</rdfs:comment>  
  <owl:equivalentClass rdf:resource="#Automobile"/>  
</owl:DeprecatedClass>
```



DeprecatedProperty:

- ⇒ Property is preserved for backward-compatibility purposes, but may be phased out in the future

Example:

```
<owl:DeprecatedProperty rdf:ID="hasDriver">  
  <rdfs:comment>inverse property drives is now preferred  
  </rdfs:comment>  
  <owl:inverseOf rdf:resource="#drives" />  
</owl:DeprecatedProperty>
```



AnnotationProperty:

- ⇒ Declares a property that is used as an annotation
- ⇒ The object of an annotation property must be either a data literal, a URI reference, or an individual

Example:

```
<owl:AnnotationProperty rdf:about="&dc;creator"/>

<owl:Class rdf:about="#MusicalWork">
  <rdfs:label>Musical work</rdfs:label>
  <dc:creator>N.N.</dc:creator>
</owl:Class>
```



OntologyProperty:

- ⇒ Properties that apply to the ontology as a whole
- ⇒ Instances of this class must have the class `owl:Ontology` as their domain and range

Example:

```
<rdf:Property rdf:ID="incompatibleWith">  
  <rdfs:label>incompatibleWith</rdfs:label>  
  <rdf:type rdf:resource="#OntologyProperty"/>  
  <rdfs:domain rdf:resource="#Ontology"/>  
  <rdfs:range rdf:resource="#Ontology"/>  
</rdf:Property>
```



oneOf:

- ⇒ Classes can be described by enumeration of the individuals that make up the class, i. e., the members of the class are exactly the set of enumerated individuals

Example:

```
<owl:Class rdf:ID="WineColor">
  <rdfs:subClassOf rdf:resource="#WineDescriptor"/>
  <owl:oneOf rdf:parseType="Collection">
    <owl:Thing rdf:about="#White"/>
    <owl:Thing rdf:about="#Rose"/>
    <owl:Thing rdf:about="#Red"/>
  </owl:oneOf>
</owl:Class>
```



disjointWith:

- ⇒ Classes may be stated to be disjoint from each other
- ⇒ Such statements are mainly used to avoid inconsistencies

Example:

```
<owl:Class rdf:ID="Pasta">  
  <rdfs:subClassOf rdf:resource="#EdibleThing"/>  
  <owl:disjointWith rdf:resource="#Meat"/>  
  <owl:disjointWith rdf:resource="#Fowl"/>  
  <owl:disjointWith rdf:resource="#Seafood"/>  
  <owl:disjointWith rdf:resource="#Dessert"/>  
  <owl:disjointWith rdf:resource="#Fruit"/>  
</owl:Class>
```



equivalentClass:

- ⇒ Same meaning as in OWL Lite
- ⇒ May additionally be complex class definitions

Example:

```
<owl:Class rdf:ID="TexasThings">
  <owl:equivalentClass>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#locatedIn"/>
      <owl:someValuesFrom rdf:resource="#TexasRegion"/>
    </owl:Restriction>
  </owl:equivalentClass>
</owl:Class>
```



`rdfs:subClassOf:`

- ⇒ Same meaning as in OWL Lite
- ⇒ May additionally be complex class definitions

Example:

```
<owl:Class rdf:ID="Wine">
  <rdfs:subClassOf rdf:resource="&food;PotableLiquid"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#madeFromGrape"/>
      <owl:minCardinality rdf:datatype="&xsd;nonNegativeInteger">
        1</owl:minCardinality>
      </owl:Restriction>
    </rdfs:subClassOf>
```



unionOf:

⇒ Boolean combination of classes and/or restrictions

Example:

```
<owl:Class rdf:ID="Fruit">  
  <owl:unionOf rdf:parseType="Collection">  
    <owl:Class rdf:about="#SweetFruit"/>  
    <owl:Class rdf:about="#NonSweetFruit"/>  
  </owl:unionOf>  
</owl:Class>
```



complementOf:

⇒ Boolean combination of classes and/or restrictions

Example:

```
<owl:Class rdf:ID="ConsumableThing"/>
```

```
<owl:Class rdf:ID="NonConsumableThing">
```

```
  <owl:complementOf rdf:resource="#ConsumableThing"/>
```

```
</owl:Class>
```



intersectionOf:

⇒ Boolean combination of classes and/or restrictions

Example:

```
<owl:Class rdf:ID="WhiteWine">
  <owl:intersectionOf rdf:parseType="Collection">
    <owl:Class rdf:about="#Wine"/>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasColor"/>
      <owl:hasValue rdf:resource="#White"/>
    </owl:Restriction>
  </owl:intersectionOf>
</owl:Class>
```



minCardinality:

- ⇒ Stated on a property with respect to a particular class
- ⇒ Specifies the minimum number of elements in a relation

Example:

```
<owl:Class rdf:ID="Tricycle">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasWheels"/>
      <owl:minCardinality rdf:datatype="&xsd;nonNegativeInteger">
        3</owl:minCardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```



maxCardinality:

- ⇒ Stated on a property with respect to a particular class
- ⇒ Specifies the maximum number of elements in a relation

Example:

```
<owl:Class rdf:ID="Tricycle">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasWheels"/>
      <owl:maxCardinality rdf:datatype="xsd:nonNegativeInteger">
        3</owl:maxCardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```



cardinality:

- ⇒ Permits the specification of exactly the number of elements in a relation

Example:

```
<owl:Class rdf:ID="Tricycle">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasWheels"/>
      <owl:cardinality rdf:datatype="&xsd;nonNegativeInteger">
        3</owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```



hasValue:

- ⇒ A property can be required to have a certain individual as a value
- ⇒ Allows for the specification of classes based on the existence of particular property values

Example:

```
<owl:Class rdf:ID="Burgundy">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasSugar"/>
      <owl:hasValue rdf:resource="#Dry"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```



- References:

- *OWL Web Ontology Language Overview*
- *OWL Web Ontology Language Guide*
- *OWL Web Ontology Language Reference*

