Web Ontology Language (OWL)

- Need meaning beyond an object-oriented type system
  - RDF (with RDFS) captures the basics, approximating an object-oriented type system
  - OWL provides some of the rest
- OWL standardizes constructs to capture such subtleties of meaning
- OWL builds on RDF, by limiting it
  - Limiting syntax
  - Limiting possible interpretations
- OWL assigns standard semantics to new terms

OWL in Brief

- Specifies classes and properties in description logic (DL)
  - Class operators analogous to Boolean operators and, not, and or
  - Constraints on properties: transitive, ...
  - Restrictions: constructs unique to DL
- OWL 1 has “Species” or Dialects
  - OWL Full
  - OWL DL
  - OWL Lite

Custom Metadata Vocabularies

- Metadata for services and information resources presupposes custom vocabularies
- Need standard semantics for the metadata to remove ambiguity despite heterogeneity

```
<Mammal rdf:ID='Mary'/>
<Mammal rdf:ID='John'>
  <hasParent rdf:resource='#Mary'/>
</Mammal>
```

Ontologies to Define Vocabulary Semantics

Example of a trivial ontology defining our vocabulary

- Uses simple subclasses and properties
  - Disjointness goes beyond RDF
  - Object properties refine RDF properties; relate two objects

```
<owl:Class rdf:ID="Mammal">
  <rdfs:subClassOf rdf:resource="#Animal"/>
  <owl:disjointWith rdf:resource="#Reptile"/>
</owl:Class>

<owl:ObjectProperty rdf:ID="hasParent">
  <rdfs:domain rdf:resource="#Animal"/>
  <rdfs:range rdf:resource="#Animal"/>
</owl:ObjectProperty>
```

Simple Inference

Find a model, if any exists

- Given the definition for the property hasParent and the snippet

```
<owl:Thing rdf:ID="Fido">
  <hasParent rdf:resource="#Rover"/>
</owl:Thing>
```

we can infer that Fido is an Animal

OWL Entities and Relationships

Constructing OWL Classes

- Explicitly

```
<owl:Class rdf:ID="Mammal">
  <rdfs:subClassOf rdf:resource="#Animal"/>
  <owl:disjointWith rdf:resource="#Reptile"/>
</owl:Class>
```

- Anonymously via formal expressions using operators analogous to set operators:
  intersectionOf, unionOf, complementOf

```
<owl:Class rdf:ID='SugaryBread'>
  <owl:intersectionOf rdf:parseType='Collection'>
    <owl:Class rdf:about='#Bread'/>
    <owl:Class rdf:about='#SweetFood'/>
  </owl:intersectionOf>
</owl:Class>
```

Restrictions Conceptually

A unique feature of description logics

- Analogous to division in arithmetic: define classes in terms of a restriction that they satisfy with respect to a given property
- Anonymous: typically included in a class def to enable referring them
- Key primitives are
  - someValuesFrom a specified class
  - allValuesFrom a specified class
  - hasValue equal to a specified individual or data type
  - minCardinality
  - maxCardinality
  - cardinality (when maxCardinality equals minCardinality)

Examples of Restrictions: 1

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

<owl:Restriction>
      <owl:onProperty rdf:resource='#bakes'/>
      <owl:someValuesFrom rdf:resource='#Bread'/>
</owl:Restriction>
```

Examples of Restrictions: 2

- The maker of a Wine must be a Winery
  - The allValuesFrom restriction is on the hasMaker property of this Wine class
  - (Makers of other products such as cheese are not constrained by this local restriction)

```
<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>
```

Axioms Conceptually

Assertions that are given to be true

- Can be especially powerful in combination with other axioms, which may come from different documents
- Some primitives
    - rdfs:subClassOf
    - owl:equivalentClass

Examples of Axioms

```
<owl:AllDifferent> <!-- in essence, pair-wise inequalities>
  <owl:distinctMembers rdf:parseType='Collection'>
   <ex:Country rdf:ID='India'/>
   <ex:Country rdf:ID='Russia'/>
   <ex:Country rdf:ID='USA'/>
  <owl:distinctMembers/>
</owl:AllDifferent>

<ex:Country rdf:ID='Iran'/>
<ex:Country rdf:ID='Persia'>
  <owl:sameIndividualAs rdf:resource='#Iran'/>
</ex:Country>
```

Restrictions versus Axioms

- Axioms are global assertions that can be used as the basis for further inference
- Restrictions are constructors
- A restriction on hasFather of maxCardinality of 1
  - Does **not** mean all animals have zero or one fathers
  - Means the class of animals who have zero or one fathers: this class may or may not have any instances
- Often, to achieve the desired effect, we would have to combine restrictions with axioms (such as based on equivalentClass), e.g.,
  - A restriction on hasFather of maxCardinality of 1
  - An axiom asserting this restriction is equivalent to Animal

Inference

Like RDF, OWL is about meaning, not syntax

- Statements from different documents about the same URI are automatically conjoined
- OWL can be surprising to the uninitiated
  - Integrity constraint: no one can have more than one mother
  - Declare a fact: Mary is John's mother
  - Declare a fact: Jane is John's mother
- What will you conclude?
  - A traditional DBMS would declare an integrity violation
  - An OWL reasoner would say Mary = Jane

Dialects Compared

- OWL DL
  - Core dialect, includes DL primitives
  - Not necessarily (but often) tractable
- OWL Lite
  - Limits OWL DL constructs to ensure tractability
  - No disjointWith, complementOf, unionOf, hasValue
  - Enumeration (oneOf)
  - intersectionOf only for two or more class names or restrictions
  - equivalentClass: class names to names or restrictions
  - rdfs:subClassOf: class names to names or restrictions
  - allValuesFrom and someValuesFrom: to class names or datatype names
  - rdf:type: to class names or restrictions
  - rdf:domain: class names
  - rdf:range: to class names or datatype names
- OWL Full
  - Extremely general: allows all RDF syntax
  - Potentially intractable (undecidable)
  - Supports fancy expressiveness needs and introducing new concepts into the standard

Expressiveness Limitations: 1

OWL DL cannot express some simple requirements

- Non-tree models: because instance variables are implicit in OWL restrictions, OWL cannot express conditions that require that two variables be identified
  - Think of siblings—two people who have the same parents—but in terms of classes
  - Do the same thing with class definitions

Expressiveness Limitations: 2

Specialized properties

- Cannot state that the child of a mammal must be a mammal and so on, without
  - Defining new child properties for each class
  - Adding an axiom for each class stating that it is a subClassOf the restriction of hasChild to itself
- Analogous to the problem in a strongly typed object-oriented language without generics
  - You have to typecast the contents of a hash table or linked list

Expressiveness Limitations: 3

Constraints among individuals and defeasibility

- Constraints among individuals
  - Can define ETHusband: class of persons who have been married to Elizabeth Taylor
  - Cannot define tall person: class of persons whose height is above a certain threshold
- Cannot capture defeasibility (also known as nonmonotonicity)
  - Birds fly
  - Penguins are birds
  - Penguins don't fly

OWL Summary

OWL builds on RDF to provide a rich vocabulary for capturing knowledge

- Synthesizes a lot of excellent work on discrete, taxonomic knowledge representation
- Fits well with describing information resources—a basis for describing metadata vocabularies
- Critical for unambiguously describing services so they can be selected and suitably engaged

Modeling Exercise

- Student (S); faculty member (F); regular faculty member (R); department (D); thesis committee (T)
- An S belongs to exactly one D
- An R is an F
- An R advises zero or more Ss
- An F is affiliated with one or more Ds
- An S is advised by exactly one R
- An S is evaluated by exactly one T
- A T evaluates exactly one S
- A T has three or more Fs as its members
- Exactly one of the members of a T is its chair, who is an R