A Language for Ontology Engineering: OWL and Rules

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- Ontology Languages (OWL and OWL with Rules)
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Ontology

Definitions of Related Terms

- A **controlled vocabulary** is a list of terms that have been enumerated explicitly and controlled by a controlled vocabulary registration authority.

- A **taxonomy** is a collection of controlled vocabulary terms organized into a hierarchical structure. Each term in a taxonomy is in one or more parent-child relationships to other terms in the taxonomy. [ETYMOLOGY: 19th Century: from French *taxonomie,* from Greek *taxis* order + -nomy]

- A **thesaurus** is a networked collection of controlled vocabulary terms including their synonyms and related terms, i.e., a thesaurus uses associative relationships in addition to parent-child relationships. [ETYMOLOGY: 18th Century: from Latin, Greek: treasure]

Definition of Ontology

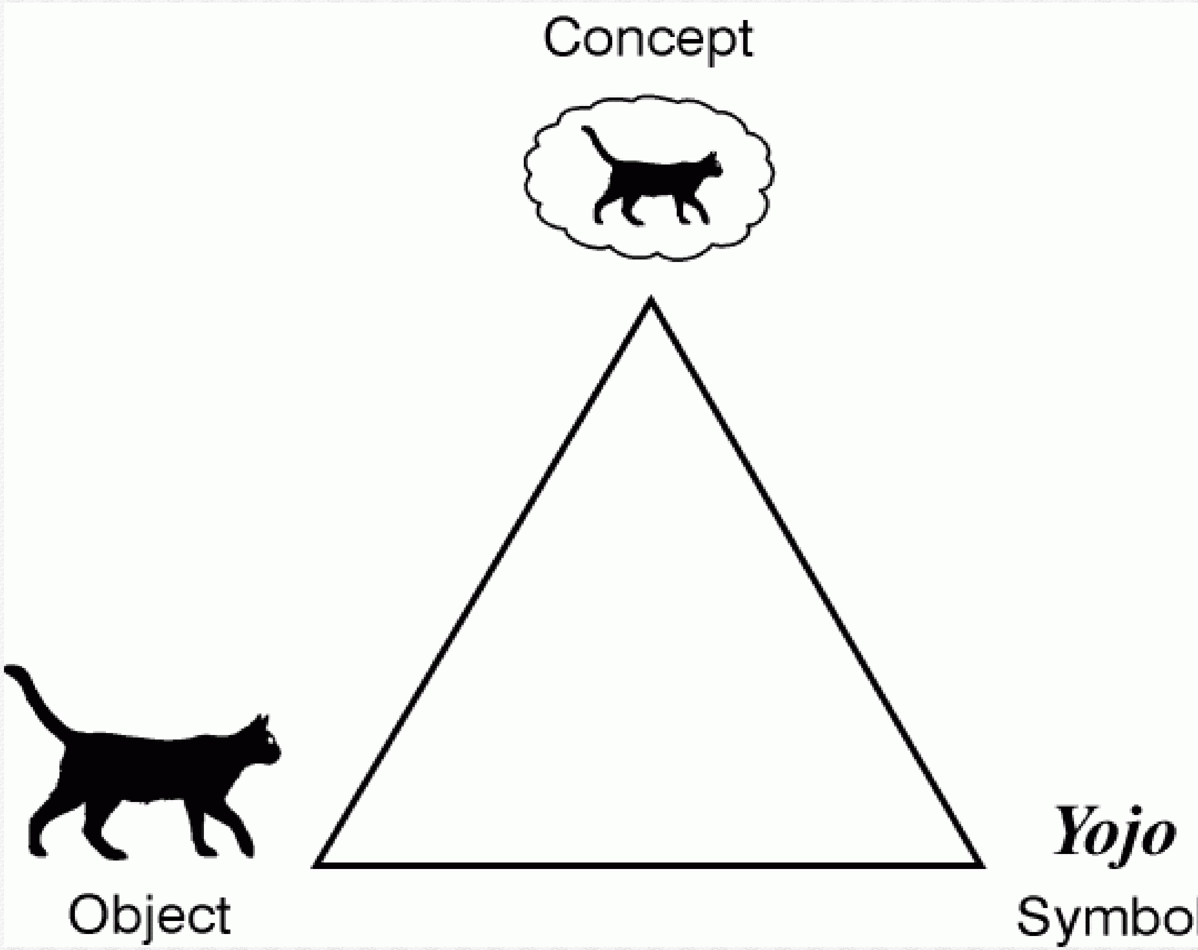
- Webster's Definition

  1 : a branch of metaphysics concerned with the nature and relations of being
  2 : a particular theory about the nature of being or the kinds of existents
- The word ontology is from the Greek *ontos* for being and *logos* for word.
- People use the word **ontology** to mean different things, e.g. glossaries & data dictionaries, thesauri & taxonomies, schemas & data models, and formal ontologies & inference.

Ontology in Computer Science

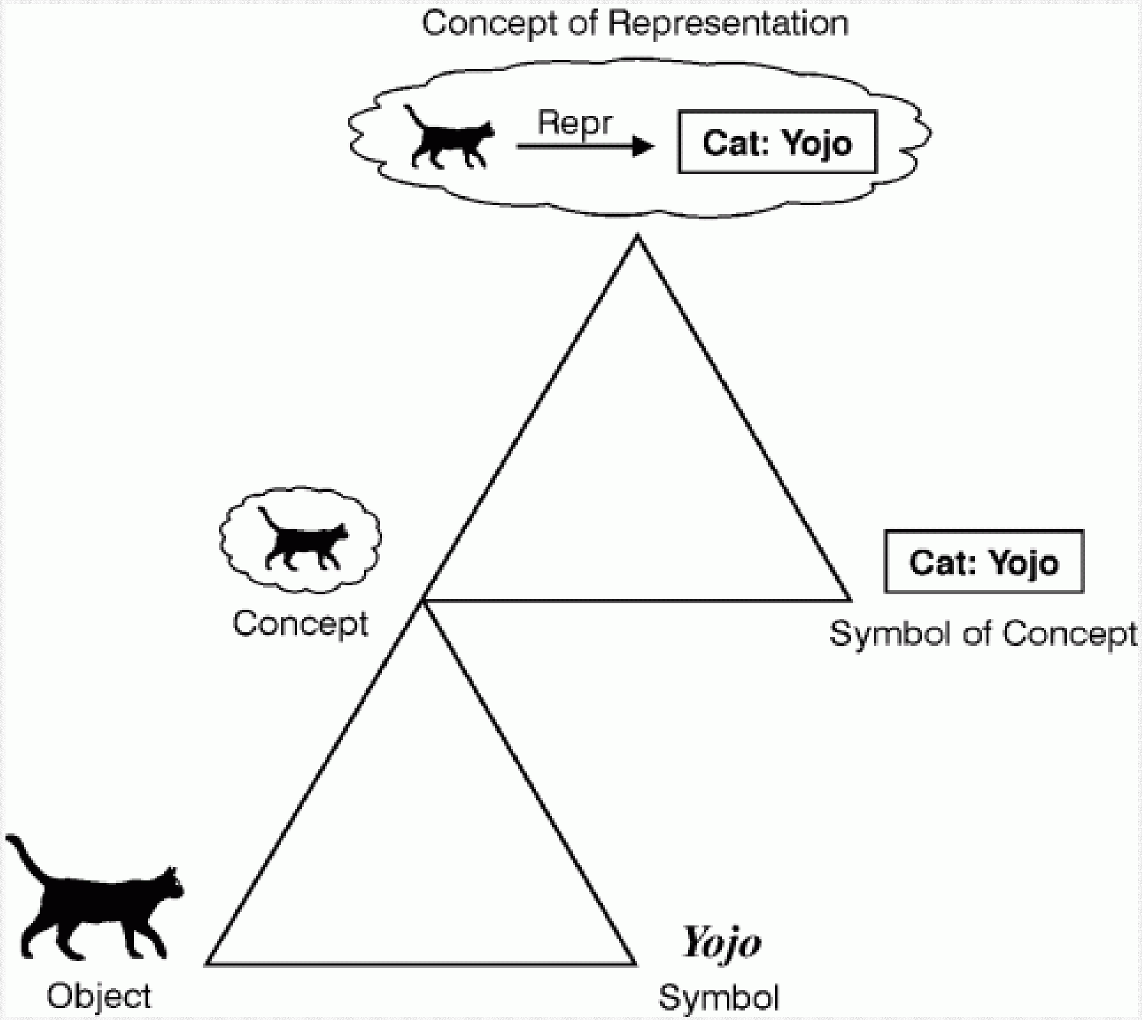
- John McCarthy first used of the term *ontology* in 1980 in the paper: “Circumscription – A Form of Non-Monotonic Reasoning”, Artificial Intelligence, 5: 13, 27–39.
- An ontology is
  - *a formal, explicit specification of a shared conceptualization* [Gruber93]
  - *a common vocabulary and agreed upon meanings to describe a domain of interest*
- Meanings of the keywords:
  - *conceptualization*: abstraction of some real-world phenomenon
  - *shared*: acceptance by a community, not restricted to some individuals
  - *specification*: definition
  - *explicit*: crystal-clear declarative meaning
  - *formal*: machine-processability
- In short, an ontology provides
  - a *common vocabulary* of terms
  - declarative definition of the *meaning of the terms* (semantics)
  - a *shared understanding* for people as well as machines

Object-Concept-Representation



[Sowa]

Meta-Concept



[Sowa]

Ontology Engineering

Definition

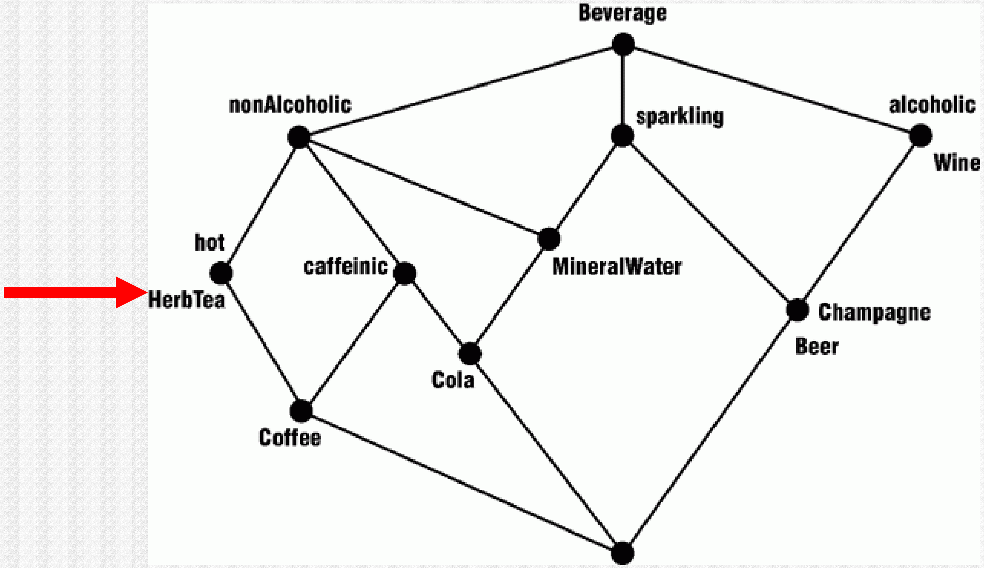
- **Ontology Engineering** deals with the representation, design, development, implementation and application of ontologies.
- Ontology Engineering tasks include:
  - Conceptualization
  - Determination of concept relationships, axioms and constraints
  - Formulation of ontology representation
  - Implementation of the ontology representation in an ontology language
  - Application of the ontology

Conceptualization Techniques

- Formal Concept Analysis (FCA)

	Attributes				
Concept Types	nonalcoholic	hot	alcoholic	caffeinic	sparkling
HerbTea	x	x			
Coffee	x	x		x	
MineralWater	x				x
Wine			x		
Beer			x		x
Cola	x			x	x
Champagne			x		x

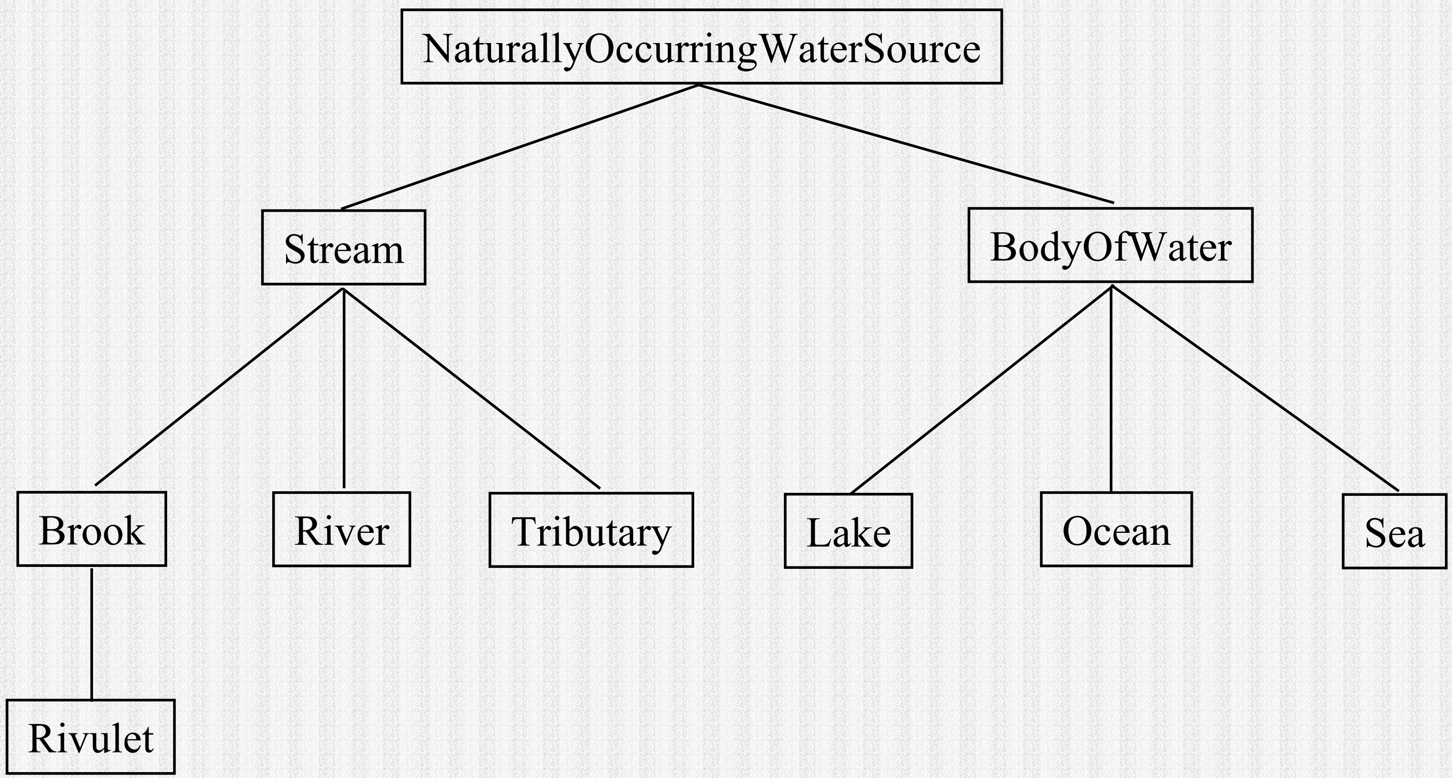
Table of beverage types and attributes



Concept Lattice

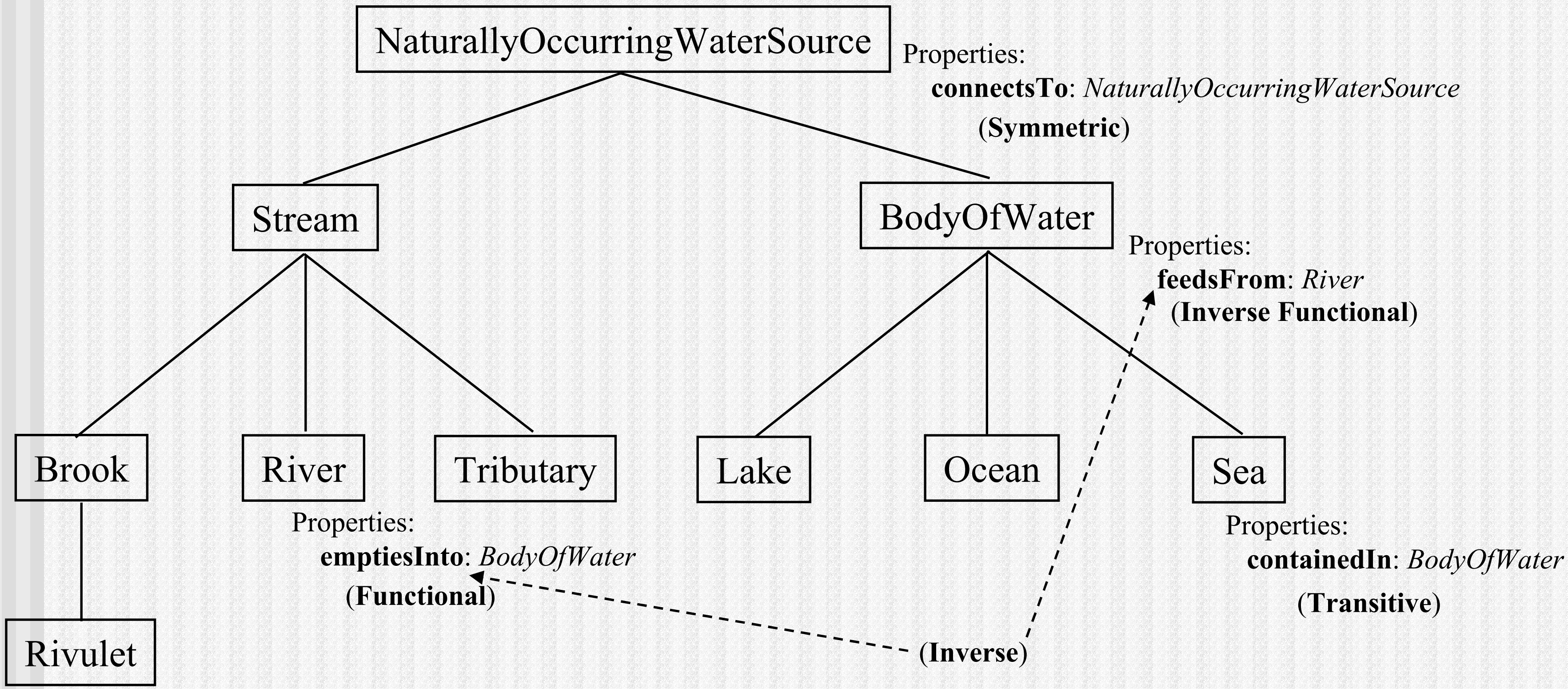
[Sowa]

Conceptualization of a Water Ontology



[Costello and Jacobs]

Determination of Water Ontology Properties



[Costello and Jacobs]

Ontology Languages

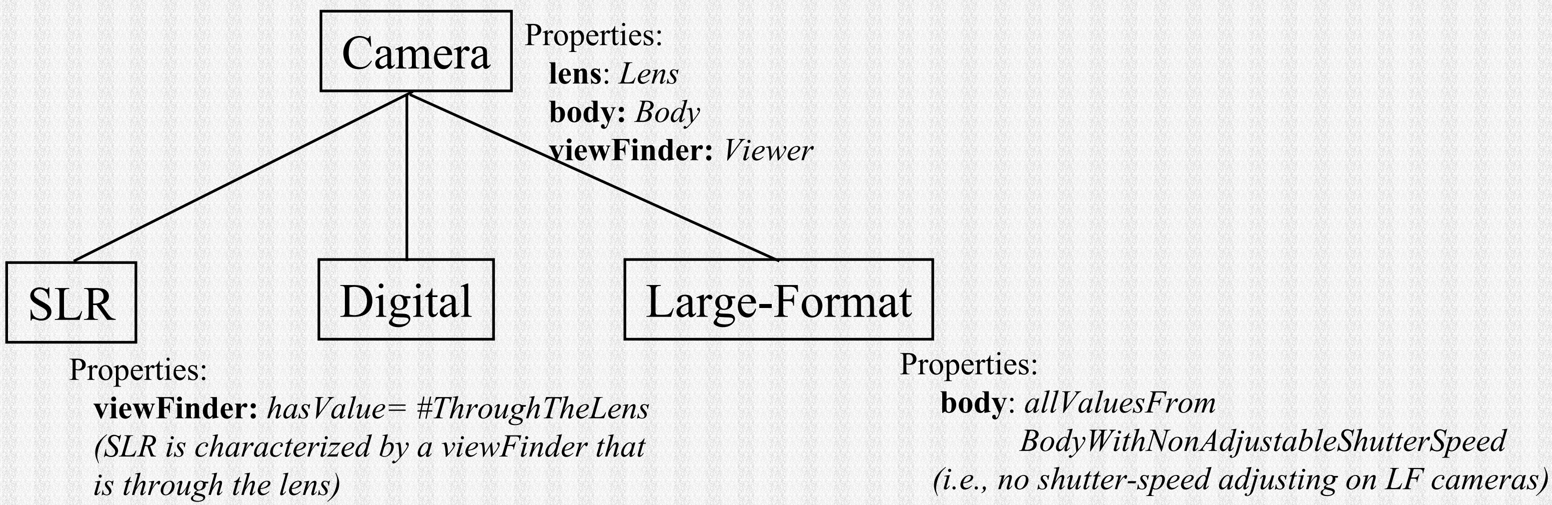
OWL (Web Ontology Language)

- OWL is an XML vocabulary that is used to define classes, their properties, as well as class and property relationships.
- OWL can define
  - Classes
  - Properties
  - Individuals
  - Subclass and other types of class relationships
  - Property relationships
  - Restrictions for property values
  - Individual relationships
- OWL is an extension of RDFS (Resource Description Framework Schema)
- OWL enables machine-processable semantics.

Examples of OWL Vocabulary

- **subClassOf** asserts that one class of items is a subset of another class of items
- **equivalentProperty** asserts that one property is equivalent to another
- **sameIndividualAs** asserts that one instance is the same as another instance
- **maxCardinality** specifies the maximum number of objects satisfying a property

Camera Ontology



[Costello and Jacobs]

Example of using OWL to define two terms and their relationship

Example: Define the terms "Camera" and "SLR".
State that SLRs are a type of Camera.

These two terms (classes) and their relationship is defined using the OWL vocabulary

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

```
<owl:Class rdf:ID="SLR">
    <rdfs:subClassOf rdf:resource="#Camera"/>
</owl:Class>
```

[Costello and Jacobs]

Relationship between focal-length and lens size

This OWL element states that focal-length is equivalent to lens size.

```
<owl:DatatypeProperty rdf:ID="focal-length">
        <owl:equivalentProperty rdf:resource="#size"/>
        <rdfs:domain rdf:resource="#Lens"/>
        <rdfs:range rdf:resource="&xsd;#string"/>
</owl:DatatypeProperty>
```

"focal-length is synonymous with (lens) size"

[Costello and Jacobs]

Summary of OWL Vocabulary: Class Constructors

- **allValuesFrom**: P(x,y) and y=allValuesFrom(C)
- **someValuesFrom**: P(x,y) and y=someValuesFrom(C)
- **cardinality**: cardinality(P) = N
- **minCardinality**: minCardinality(P) = N
- **maxCardinality**: maxCardinality(P) = N
- **intersectionOf**: C = intersectionOf(C1, C2, …)
- **unionOf**: C = unionOf(C1, C2, …)
- **complementOf**: C = complementOf(C1)
- **oneOf**: C = one of(v1, v2, …)

where:

C, C1, C2: OWL descriptions

P: an OWL property

x, y: variables, OWL individuals or OWL data values

N: a number

Summary of OWL Vocabulary: Axioms

subtClassOf: C1 = subClassOf(C2)

equivalentClassOf: C1 = C2

disjointWith: C1 != C2

transitiveProperty: if P(x,y) and P(y,z) then P(x, z)

FunctionalProperty: if P(x,y) and P(x,z) then y=z

InverseOf: if P1(x,y) then P2(y,x)

InverseFunctionalProperty: if P(y,x) and P(z,x) then y=z

equivalentProperty: P1 = P2

subPropertyOf: P1 = subClassOf(P2)

equivalentPropertyOf: P1 = P2

sameIndividualAs: I1 = I2

differentFrom: I1 != I2

where:

C, C1, C2: OWL descriptions

P1, P2: OWL properties

x, y, z: variables, OWL individuals or OWL data values

I1, I2: individuals

Summary of OWL Vocabulary: Axioms

- **subtClassOf**: C1 = subClassOf(C2)
- **equivalentClassOf**: C1 = C2
- **disjointWith**: C1 != C2
- **transitiveProperty**: if P(x,y) and P(y,z) then P(x, z)
- **FunctionalProperty**: if P(x,y) and P(x,z) then y=z
- **InverseOf**: if P1(x,y) then P2(y,x)
- **InverseFunctionalProperty**: if P(y,x) and P(z,x) then y=z
- **equivalentProperty**: P1 = P2
- **subPropertyOf**: P1 = subClassOf(P2)
- **equivalentPropertyOf**: P1 = P2
- **sameIndividualAs**: I1 = I2
- **differentFrom**: I1 != I2

where:

C, C1, C2: OWL descriptions

P1, P2: OWL properties

x, y, z: variables, OWL individuals or OWL data values

I1, I2: individuals

OWL with Rules

- In order to extend the expressive power of OWL, a Semantic Web Rule Language (SWRL) has been proposed
- SWRL combines OWL DL and OWL Lite sublanguages of OWL with the Unary/Binary Datalog sublanguages of RuleML (http://www.ruleml.org), enabling Horn-like rules to be combined with an OWL knowledge base
- The proposed rules are of the form of an implication between an antecedent (body) and consequent (head), where both the antecedent and consequent consist of zero or more atoms
- The atoms can be of the form C(x), P(x,y), sameAs(x,y) or differentFrom(x,y), where C is an OWL description, P is an OWL property, and x,y are either variables, OWL individuals or OWL data values

Example of SWRL

```
<swrl:Variable rdf:ID="x1"/>
<swrl:Variable rdf:ID="x2"/>
<swrl:Variable rdf:ID="x3"/>

<ruleml:Imp>

  <ruleml:body rdf:parseType="Collection">
    <swrl:individualPropertyAtom>
      <swrl:propertyPredicate
rdf:resource="&eg;hasParent"/>
      <swrl:argument1 rdf:resource="#x1" />
      <swrl:argument2 rdf:resource="#x2" />
    </swrl:individualPropertyAtom>
    <swrl:individualPropertyAtom>
      <swrl:propertyPredicate
rdf:resource="&eg;hasSibling"/>
      <swrl:argument1 rdf:resource="#x2" />
      <swrl:argument2 rdf:resource="#x3" />
    </swrl:individualPropertyAtom>
    <swrl:individualPropertyAtom>
      <swrl:propertyPredicate rdf:resource="&eg;hasSex"/>
      <swrl:argument1 rdf:resource="#x3" />
      <swrl:argument2 rdf:resource="#male" />
    </swrl:individualPropertyAtom>
  </ruleml:body>
```

```
<ruleml:head rdf:parseType="Collection">
    <swrl:individualPropertyAtom>
      <swrl:propertyPredicate
rdf:resource="&eg;hasUncle"/>
      <swrl:argument1 rdf:resource="#x1" />
      <swrl:argument2 rdf:resource="#x3" />
    </swrl:individualPropertyAtom>
  </ruleml:head>
</ruleml:Imp>
```

This rule asserts that if x1 hasParent x2, x2 hasSibling x3, and x3 hasSex male, then x1 hasUncle x3.

XDD Modeling of OWL + Rules

XDD

XML Declarative Description (XDD)

XML | **DD Theory**

- XDD is unified, XML-based knowledge representation language with
  - well-defined declarative semantics, and
  - a support for general computation and inference mechanisms.
- It employs:
  - XML’s nested tree structure as its underlying data structure,
  - Declarative Description theory as a framework to enhance its expressive power.

Problems with SWRL

- SWRL is a mere XMLization of a subset of Horn logic
- SWRL is too verbose and is a not succinct representation of real-world domain data
- Handling of XML data by SWRL is not direct
- Efficient computational mechanism may be difficult to develop

XDD Descriptions

An XDD Description

Ordinary XML Elements

XML Expressions (Extended XML Elements with Variables)

XML Clauses

- Representing explicit information items in a particular domain and denoting a semantic unit
- Representing implicit information or a set of semantic units
- Modeling integrity constraints, rules, conditional relationships and axioms

XML Clauses

H

$\leftarrow B_1$,

B_2 ,

.

.

B_n .

Head

Body

Domain Ontologies and Contents

- A description of domain-specific ontologies and their instances encoded in an ontology language, such as OWL, becomes immediately an XDD description comprising solely ordinary XML elements.
- XML clauses can be employed to define the axiomatic semantics of each ontology modeling primitive which includes a certain notion of implication.
- XML clauses can be used to model arbitrary rules, axioms, constraints and queries.

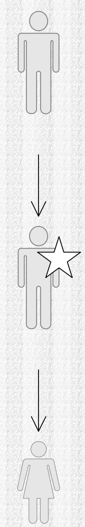
XDD Description:
Ontologies and instances

```
C1:   <owl:Class rdf:ID="Person">
              <rdfs:label>person</rdfs:label>
      </owl:Class>
C2:   <owl:ObjectProperty rdf:ID="hasChild">
              <rdfs:domain rdf:resource="#Person"/>
              <rdfs:range rdf:resource="#Person"/>
      </owl:ObjectProperty>
C3:   <owl:ObjectProperty rdf:ID="hasParent">
              <owl:inverseOf rdf:resource="#hasChild"/>
      </owl:ObjectProperty>
```

Application-specific ontology definition expressed in terms of OWL.

```
C4:   <Person rdf:about="Jack">
              <age>52</age>
              <hasChild rdf:resource= "#John"/>
              <hasAirlineMembership/>
      </Person>
C5:   <Person rdf:about="John">
              <age>29</age>
              <hasChild rdf:resource="#Jill"/>
              <hasAirlineMembership rdf:resource="#tg9000"/>
      </Person>
C6:   <Person rdf:about="Jill">
              <age>7</age>
              <hasAirlineMembership/>
      </Person>
```

Ontology instances (application data)



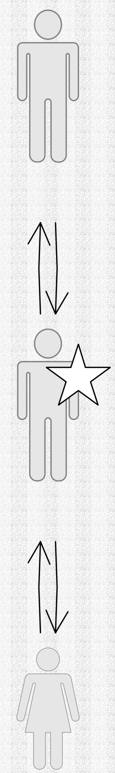
XDD Description: Ontology Axioms

If a property R is an inverse of a property P,
then for any resource X the value of a property P of which is a resource Y,
one can infer that Y also has a property R the value of which is the resource X.

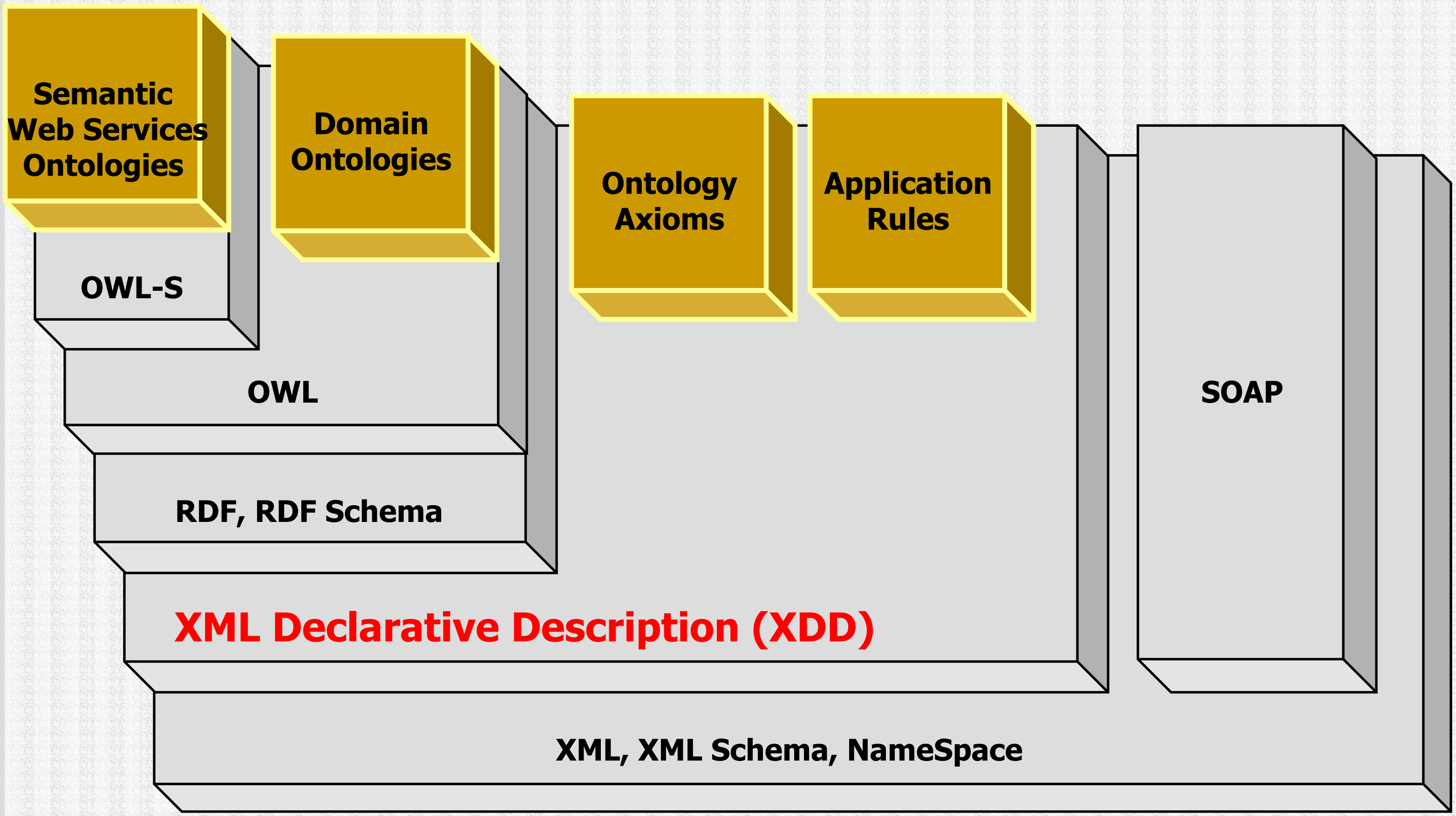
```
C7:  <$N:classB  rdf:about=$S:resourceY>
         $E:instance1Elmt
         <$S:propertyR rdf:resource=$S:resourceX/>
     </$N:classB>
         ←       <owl:ObjectProperty rdf:ID=$S:propertyR>
                     <owl:inverseOf rdf:resource=$S:propertyP/>
                     $E:inversePropertyElmt
                 </owl:ObjectProperty>,
                 <$N:classA  rdf:ID=$S:resourceX>
                     <$S:propertyP rdf:resource=$S:resourceY/>
                     $E:XProperties
                 </$N:classA>,
                 <$N:classB  rdf:ID=$S:resourceY>
                     $E:YProperties
                 </$N:classB>.
```

Derived Information

```
<Person rdf:about="John">
    <age>29</age>
    <hasChild rdf:resource="#Jill"/>
    <hasAirlineMembership
        rdf:resource="#tg9000"/>
    <hasParent rdf:resource="#Jack"/>
</Person>
<Person rdf:about="Jill">
    <age>7</age>
    <hasAirlineMembership/>
    <hasParent rdf:resource="#John"/>
</Person>
```



Language Layers with XDD



Language Layers

Conclusions

Conclusions

- Ontology Engineering (OE) involves the representation, design, development, implementation and application of ontologies
- OE requires an expressive language with efficient computational mechanism
- SWRL = OWL + XMLized subset of Horn logic
- OWL over XDD provides a succinct, expressive OWL+Rules language with efficient computational mechanism