Knowledge Representation for the Semantic Web

Winter Quarter 2010

Slides 8 – 02/25/2010

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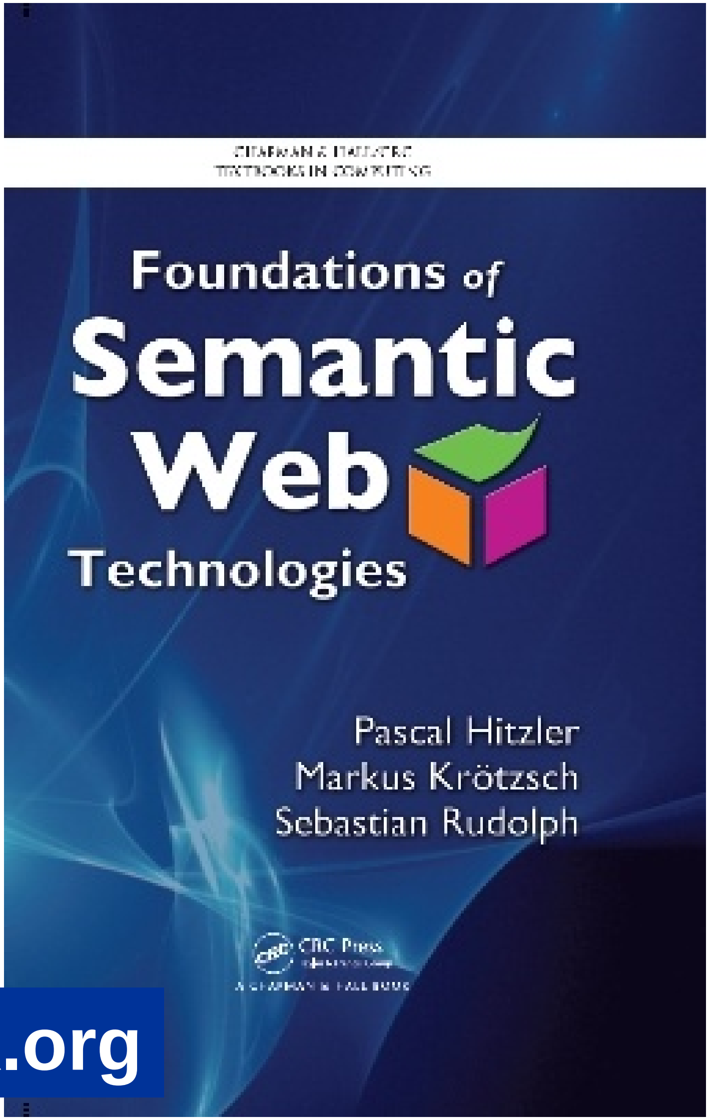
Slides are based on

Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph

Foundations of Semantic Web Technologies

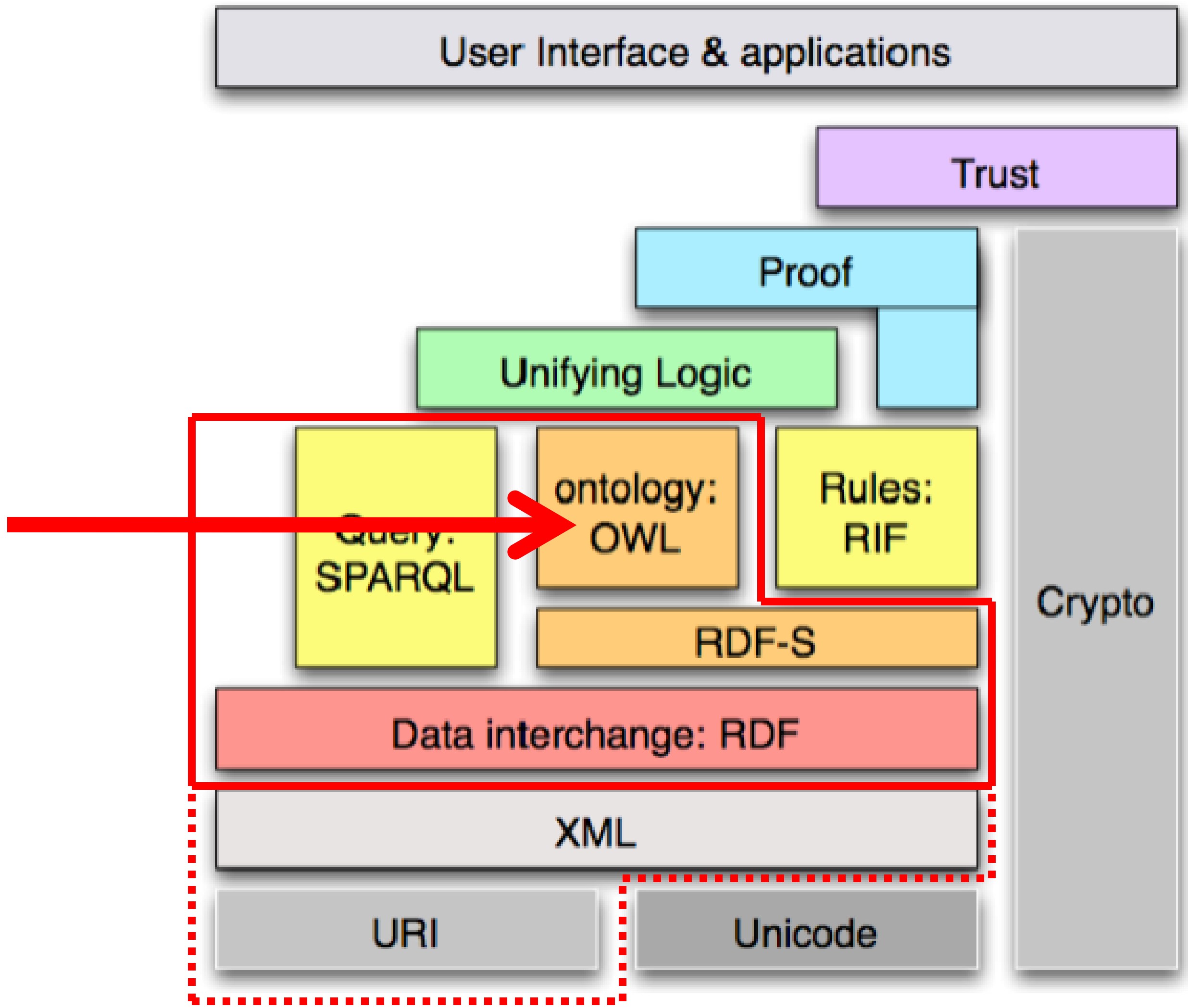
Chapman & Hall/CRC, 2010

Flyer with special offer is available.



http://www.semantic-web-book.org

Today: OWL Syntax



OWL/RDF Semantic Mismatch

```
ex:speaksWith   rdfs:domain       ex:Homo .
ex:Homo         rdfs:subClassOf   ex:Primates .
```

does not RDFS-entail

```
ex:speaksWith   rdfs:domain       ex:Primates .
```

although it is a valid OWL entailment.

It does RDFS-entail

```
rdfs:subClassOf rdf:type rdf:Property
```

which is not a valid OWL entailment.

OWL 2 Syntaxes

- **RDF/XML Syntax**
  - **The only *normative* syntax (i.e. to be OWL 2 compliant, a tool has to support this (and only this) syntax.**
- **Turtle Syntax**
  - **Straightforward Turtle version of the RDF/XML Syntax.**
  - **We will cover the RDF Syntax using Turtle or RDF/XML.**
- **Functional Style Syntax**
  - **Prefix-syntax, given as formal grammar**
  - **Clean, adjustable, modifiable, easily parsable**
  - **Used for *defining* OWL 2 in the W3C Specs.**
- **Manchester Syntax**
  - **User-friendly(?) syntax, used e.g. in Protégé 4**
- **OWL/XML Syntax**
  - **Notational variant of the Functional Style Syntax.**
  - **Does not use RDF triples, but simply XML tree structure.**

Syntax Examples

- **Many examples, translated into all syntaxes:**

- **Pascal Hitzler, Markus Krötzsch, Bijan Parsia, Peter F. Patel-Schneider, Sebastian Rudolph**
  OWL 2 Web Ontology Language: Primer.
  W3C Recommendation, 27 October 2009.
  http://www.w3.org/TR/owl2-primer/

Today’s Session: OWL Syntax

1. RDF Syntax
2. Other Syntaxes and OWL Variants
3. Class Project
4. Class Presentations

The RDFS perspective

- :mary rdf:type :Person .
- :Mother rdfs:subClassOf :Woman .
- :john :hasWife :Mary .
- :hasWife rdfs:subPropertyOf :hasSpouse

- Person(mary)
- Mother $\sqsubseteq$ Woman
- hasWife(john,mary)
- hasWife $\sqsubseteq$ hasSpouse

- :hasWife rdfs:range :Woman .
- :hasWife rdfs:domain :Man .

- $\top \sqsubseteq \forall$hasWife.Woman
- $\top \sqsubseteq \forall$hasWife^{-}.Man or $\exists$hasWife.$\top \sqsubseteq$ Man

- owl:Thing
- owl:Nothing
- owl:topProperty
- owl:bottomProperty

- $\top$
- $\bot$
- U
- *?*

owl namespace: http://www.w3.org/2002/07/owl#

SROIQ(D) constructors – overview

- ABox assignments of individuals to classes or properties
- ALC: $\sqsubseteq$, $\equiv$ for classes
  $\sqcap$, $\sqcup$, $\neg$, $\exists$, $\forall$
  $\top$, $\bot$
- SR: + property chains, property characteristics,
  role hierarchies $\sqsubseteq$
- SRO: + nominals {o}
- SROI: + inverse properties
- SROIQ: + qualified cardinality constraints
- SROIQ(D): + datatypes (including facets)

- + top and bottom roles (for objects and datatypes)
- + disjoint properties
- + Self
- + Keys (not in SROIQ(D), but in OWL)

RDF Syntax Challenges

- How do you put SROIQ(D) axioms like

$$\text{Orphan} \sqsubseteq \text{Human} \sqcap \forall \text{hasParent}.\neg\text{Alive}$$

  into a graph structure?

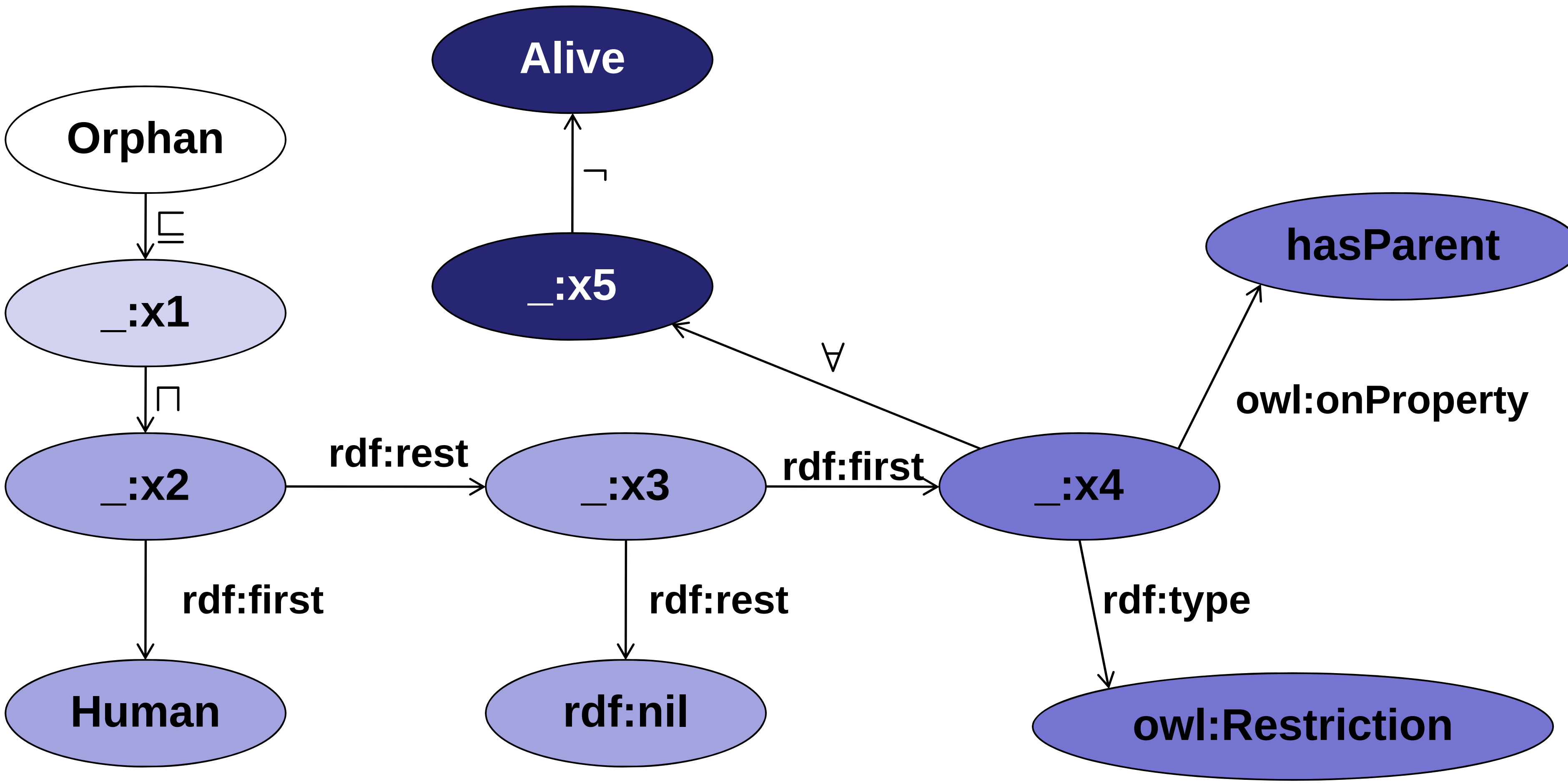
- How do you do it such that the RDF Schema semantics and the DL semantics are not violated?

- How do you do it without violating the main conceptual ideas behind RDF and DLs?

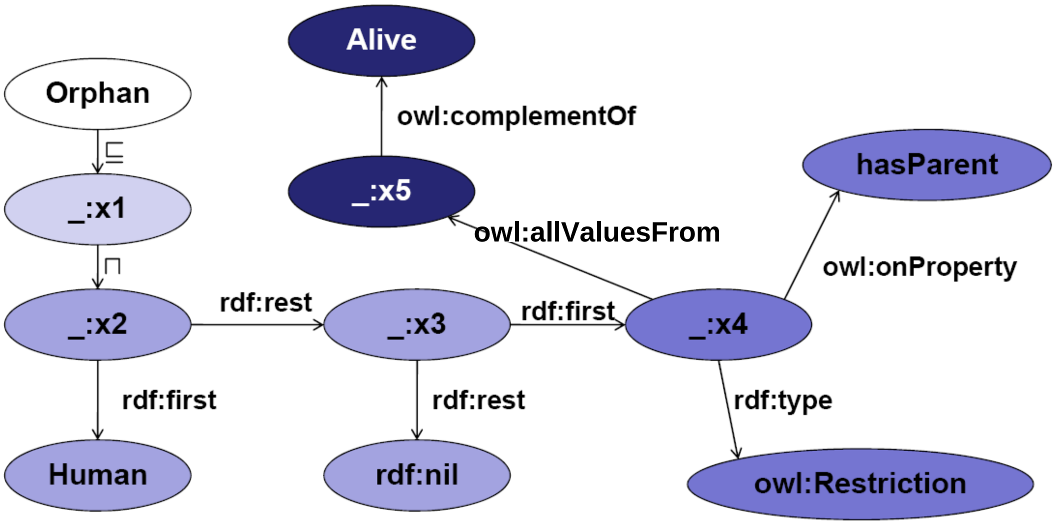
- That’s actually impossible without violating either RDF or DL. We have to do some approximations, and accept that the layering cannot be perfect.

General Idea

$$\texttt{Orphan} \sqsubseteq \texttt{Human} \sqcap \forall \texttt{hasParent}.\neg \texttt{Alive}$$



RDF Syntax

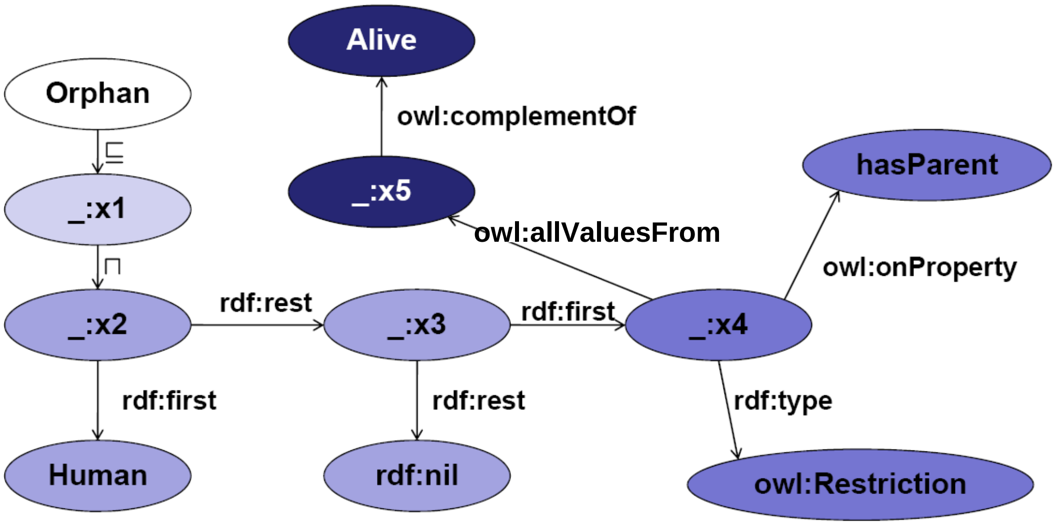


- From here on, you can basically make the RDF syntax yourself.

- You only need to know the OWL vocabulary to use and some constructs need some design decisions, which are sometimes almost arbitrary.

RDF Semantics?

- You get all kinds of entailments which are entirely irrelevant for the OWL knowledge base.



- owl:complementOf rdf:type rdf:Property .
- _:x5 owl:complementOf _:xyz .
- owl:Restriction rdf:type rdfs:Class .
- :hasParent rdf:type rdfs:Resource .
- owl:Restriction rdfs:subClassOf rdfs:Resource .
- owl:Restriction rdfs:subClassOf owl:Restriction .

OWL RDF Syntax: Individuals

```
:Mary rdf:type :Woman .
```

```
:John :hasWife :Mary .
```

```
:John owl:differentFrom :Bill .
```

$\{John\} \sqcap \{Bill\} \sqsubseteq \bot$

```
:James owl:sameAs :Jim.
```

$\{John\} \equiv \{Jim\}$

```
:John  :hasAge ”51”^^xsd:nonNegativeInteger .
```

```
[]  rdf:type               owl:NegativePropertyAssertion ;
    owl:sourceIndividual   :Bill ;
    owl:assertionProperty  :hasWife ;
    owl:targetIndividual   :Mary .
```

$\neg hasWife(Bill,Mary)$

```
[]  rdf:type               owl:NegativePropertyAssertion ;
    owl:sourceIndividual   :Jack ;
    owl:assertionProperty  :hasAge ;
    owl:targetValue        53 .
```

OWL RDF Syntax: Classes + Properties

```
:Woman rdfs:subClassOf :Person .
```

```
:Person owl:equivalentClass :Human .
```

```
[]  rdf:type      owl:AllDisjointClasses ;
    owl:members   ( :Woman   :Man ) .
```

Woman $\sqcap$ Man $\sqsubseteq \bot$

```
:hasWife rdfs:subPropertyOf :hasSpouse .
```

```
:hasWife rdfs:domain :Man ;
         rdfs:range  :Woman .
```

OWL RDF Syntax: Complex Classes

```
:Mother  owl:equivalentClass  [
  rdf:type              owl:Class ;
  owl:intersectionOf  ( :Woman :Parent )
] .
```

Mother ≡ Woman ⊓ Parent

```
:Parent  owl:equivalentClass  [
  rdf:type      owl:Class ;
  owl:unionOf  ( :Mother :Father )
] .
```

Parent ≡ Mother ⊔ Father

```
:ChildlessPerson  owl:equivalentClass  [
  rdf:type              owl:Class ;
  owl:intersectionOf  ( :Person  [ owl:complementOf  :Parent ] )
] .
```

ChildlessPerson ≡ Person ⊓ ¬Parent

```
:Grandfather  rdfs:subClassOf  [
  rdf:type              owl:Class ;
  owl:intersectionOf  ( :Man  :Parent )
] .
```

OWL RDF Syntax: Complex Classes

Person ⊓ ¬Parent (Jack)

```
:Jack  rdf:type  [
  rdf:type              owl:Class ;
  owl:intersectionOf    ( :Person
                          [ rdf:type          owl:Class ;
                            owl:complementOf  :Parent      ]
                        )
] .
```

OWL RDF Syntax: Restrictions

```
:Parent  owl:equivalentClass  [
  rdf:type             owl:Restriction ;
  owl:onProperty       :hasChild ;
  owl:someValuesFrom   :Person
] .
```

Parent $\equiv \exists$hasChild.Person

```
:Orphan  owl:equivalentClass  [
  rdf:type            owl:Restriction ;
  owl:onProperty      [ owl:inverseOf  :hasChild ] ;
  owl:allValuesFrom   :Dead
] .
```

Orphan $\equiv \forall$ hasChild^{-}.Dead

OWL RDF Syntax: Restrictions

```
:JohnsChildren  owl:equivalentClass  [
  rdf:type          owl:Restriction ;
  owl:onProperty    :hasParent ;
  owl:hasValue      :John
] .
```

JohnsChildren $\equiv$ $\exists$hasParent.{John}

```
:NarcisticPerson owl:equivalentClass  [
  rdf:type          owl:Restriction ;
  owl:onProperty    :loves ;
  owl:hasSelf       "true"^^xsd:boolean .
] .
```

NarcisticPerson $\equiv$ $\exists$loves.Self

OWL RDF Syntax: Restrictions

$\leq$4 hasChild.Parent (John)

```
:John  rdf:type  [
  rdf:type                        owl:Restriction ;
  owl:maxQualifiedCardinality     "4"^^xsd:nonNegativeInteger ;
  owl:onProperty                  :hasChild ;
  owl:onClass                     :Parent
] .
```

```
:John  rdf:type  [
  rdf:type                        owl:Restriction ;
  owl:minQualifiedCardinality     "2"^^xsd:nonNegativeInteger ;
  owl:onProperty                  :hasChild ;
  owl:onClass                     :Parent
] .
```

$\geq$2 hasChild.Parent (John)

```
:John  rdf:type  [
  rdf:type                     owl:Restriction ;
  owl:qualifiedCardinality     "3"^^xsd:nonNegativeInteger ;
  owl:onProperty               :hasChild ;
  owl:onClass                  :Parent
] .
```

=3 hasChild.Parent (John)

OWL RDF Syntax: Restrictions

```
:John  rdf:type  [
  rdf:type          owl:Restriction ;
  owl:cardinality   "5"^^xsd:nonNegativeInteger ;
  owl:onProperty    :hasChild
] .
```

$=5$ hasChild.$\top$ (John)

```
:MyBirthdayGuests  owl:equivalentClass  [
  rdf:type   owl:Class ;
  owl:oneOf  ( :Bill  :John  :Mary )
] .
```

MyBirthdayGuests $\equiv$ {Bill, John, Mary}

OWL RDF Syntax: Properties

```
:hasParent owl:inverseOf :hasChild .
```

```
:Orphan  owl:equivalentClass  [
  rdf:type             owl:Restriction ;
  owl:onProperty       [ owl:inverseOf  :hasChild ] ;
  owl:allValuesFrom   :Dead
] .
```

$\text{Orphan} \equiv \forall \text{hasChild}^{-}.\text{Dead}$

```
:hasSpouse  rdf:type  owl:SymmetricProperty .
```

```
:hasChild  rdf:type  owl:AsymmetricProperty .
```

```
:hasParent  owl:propertyDisjointWith  :hasSpouse .
```

```
:hasRelative  rdf:type  owl:ReflexiveProperty .
```

```
:parentOf  rdf:type  owl:IrreflexiveProperty .
```

```
:hasHusband  rdf:type  owl:FunctionalProperty .
```

```
:hasHusband  rdf:type  owl:InverseFunctionalProperty .
```

```
:hasAncestor  rdf:type  owl:TransitiveProperty .
```

OWL RDF Syntax: Properties

```
:hasGrandparent owl:propertyChainAxiom ( :hasParent :hasParent ).
```

$$\textbf{hasParent} \circ \textbf{hasParent} \sqsubseteq \textbf{hasGrandParent}$$

```
:Person owl:hasKey ( :hasSSN ) .
```

In OWL 2 a collection of (data or object) properties can be assigned as a key to a class expression. This means that each named instance of the class expression is uniquely identified by the set of values which these properties attain in relation to the instance.

OWL RDF Syntax: Datatypes

```
:personAge  owl:equivalentClass
 [ rdf:type  rdfs:Datatype;
   owl:onDatatype  xsd:integer;
   owl:withRestrictions (
      [ xsd:minInclusive  "0"^^xsd:integer ]
      [ xsd:maxInclusive  "150"^^xsd:integer ]
   )
 ] .
```

Datatype *facets*

```
:majorAge  owl:equivalentClass
  [ rdf:type  rdfs:Datatype;
    owl:intersectionOf (
       :personAge
       [ rdf:type  rdfs:Datatype;
         owl:datatypeComplementOf  :minorAge ]
    )
  ] .
```

```
:toddlerAge  owl:equivalentClass
  [ rdf:type rdfs:Datatype;
  owl:oneOf (  "1"^^xsd:integer  "2"^^xsd:integer )
] .
```

Essential OWL Features

Feature	Related OWL vocabulary	FOL	DL
top/bottom class	`owl:Thing/owl:Nothing`	(axiomatise)	$\top/\bot$
Class intersection	`owl:intersectionOf`	$\wedge$	$\sqcap$
Class union	`owl:unionOf`	$\vee$	$\sqcup$
Class complement	`owl:complementOf`	$\neg$	$\neg$
Enumerated class	`owl:oneOf`	(ax. with $\approx$)	$\{a\}$
Property restrictions	`owl:onProperty`		
Existential	`owl:someValueFrom`	$\exists y$ …	$\exists R.C$
Universal	`owl:allValuesFrom`	$\forall y$ …	$\forall R.C$
Min. cardinality	`owl:minQualifiedCardinality` `owl:onClass`	$\exists y1 \ldots yn.$ …	$\geq n$ S.C
Max. cardinality	`owl:maxQualifiedCardinality` `owl:onClass`	$\forall y1 \ldots yn+1.$ … $\rightarrow$ …	$\leq n$ S.C
Local reflexivity	`owl:hasSelf`	R(x,x)	$\exists R.Self$

Essential OWL Features

Feature	Related OWL vocabulary	DL
Property chain	`owl:propertyChainAxiom`	$\circ$
Inverse	`owl:inverseOf`	R^-
Key	`owl:hasKey`	
Property disjointness	`owl:propertyDisjointWith`	Dis(R,S)
Property characteristics	`rdf:hasType`	
Symmetric	`owl:SymmetricProperty`	Sym(R)
Asymmetric	`owl:AsymmetricProperty`	Asy(R)
Reflexive	`owl:ReflexiveProperty`	Ref(R)
Irreflexive	`owl:IrreflexiveProperty`	Irr(R)
Transitivity	`owl:TransitiveProperty`	Tra(R)

Subclass	`rdfs:subClassOf`	$\forall x.C(x) \rightarrow D(x)$	$C \sqsubseteq D$
Subproperty	`rdfs:subPropertyOf`	$\forall x,y.R(x,y) \rightarrow S(x,y)$	$R \sqsubseteq S$

OWL RDF Syntax: Header

```
<http://example.com/owl/families> rdf:type owl:Ontology .
```

```
@prefix : <http://example.com/owl/families/> .
@prefix otherOnt: <http://example.org/otherOntologies/families/> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
```

```
<http://example.com/owl/families>
owl:imports <http://example.org/otherOntologies/families/> .
```

OWL RDF Syntax: Header

```
@prefix : <http://example.com/owl/families/> .
@prefix otherOnt: <http://example.org/otherOntologies/families/> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
```

```
<http://example.com/owl/families>
owl:imports <http://example.org/otherOntologies/families/> .
```

```
:Mary       owl:sameAs              otherOnt:MaryBrown .
:John       owl:sameAs              otherOnt:JohnBrown .
:Adult      owl:equivalentClass     otherOnt:Grownup .
:hasChild   owl:equivalentProperty  otherOnt:child .
:hasAge     owl:equivalentProperty  otherOnt:age .
```

OWL RDF Syntax: Declarations

Each class, property, or individual needs to be declared.

```
:John     rdf:type owl:NamedIndividual .
:Person   rdf:type owl:Class .
:hasWife  rdf:type owl:ObjectProperty .
:hasAge   rdf:type owl:DatatypeProperty .
```

Punning:

Same URI can stand e.g. for both an individual and a class:

```
:John      rdf:type     :Father .
:Father    rdf:type     :SocialRole .
```

Semantics: This is semantically interpreted as if the two occurrences of `Father` **were in fact distinct.**

Not allowed: E.g. use of a URI for both object and datatype property.

OWL RDF Syntax: Annotations

```
:Person  rdfs:comment  "Represents the set of all people."^^xsd:string .
```

```
:Man rdfs:subClassOf :Person .
[]  rdf:type          owl:Axiom ;
    owl:annotatedSource     :Man ;
    owl:annotatedProperty  rdfs:subClassOf ;
    owl:annotatedTarget     :Person ;
    rdfs:comment      "States that every man is a person."^^xsd:string .
```

Today's Session: OWL Syntax

1. RDF Syntax
2. Other Syntaxes and OWL Variants
3. Class Project
4. Class Presentations

OWL DL and OWL Full

- OWL 2 DL is the “description logic” version of OWL
  - global restrictions from SROIQ(D) apply
  - RDF can only be used in a very controlled fashion (only what is necessary for expressing OWL axioms)
  - model-theoretic semantics of SROIQ(D) is used, called *OWL 2 Direct Semantics*
- OWL 2 Full is unrestricted OWL 2 DL plus all of RDF(S).
  - no global restrictions
  - RDF can be used freely
  - semantics is a hybrid of RDFS and OWL 2 DL semantics, called *RDF-Based Semantics*
- Both semantics are in the W3C recommendation.
  No implementations of the OWL 2 Full semantics exist.

OWL 2 Profiles

- The OWL 2 spec describes three profiles (fragments, sublanguages) which have polynomial complexity.
  - OWL EL (the description logic EL++)
    presented earlier
  - OWL QL (the description logic DL Lite$_R$)
    forthcoming class presentation
  - OWL RL (the description logic DLP)
    skipped
    - inspired by intersecting OWL with Datalog
    - implemented e.g. in Oracle 11g

OWL Functional Syntax

```
SubClassOf(
  :ChildlessPerson
  ObjectIntersectionOf(
    :Person
    ObjectComplementOf(
      ObjectSomeValuesFrom(
        ObjectInverseOf( :hasParent )
        owl:Thing
      )
    )
  )
)
```

$\text{ChildlessPerson} \sqsubseteq \text{Person} \sqcap \neg \exists \text{hasParent}^{-}.\top$

```
ClassAssertion(
  ObjectIntersectionOf(
    :Person
    ObjectComplementOf( :Parent )
  )
  :Jack
)
```

$\text{Person} \sqcap \neg\text{Parent} (\text{Jack})$

OWL Manchester Syntax

```
Class: Parent
  EquivalentTo: hasChild some Person
  EquivalentTo: Mother or Father
```

```
Class: HappyPerson
  EquivalentTo: hasChild only Happy and hasChild some Happy
Class: JohnsChildren
  EquivalentTo: hasParent value John
Class: NarcisticPerson
  EquivalentTo: loves Self
Class: Orphan
  EquivalentTo: inverse hasChild only Dead
Class: Teenager
 SubClassOf: hasAge some integer[<= 13 , >= 19]
```

```
Class: X
  SubClassOf:   Parent and hasChild max 1 and hasChild only Female
  EquivalentTo: {Mary, Bill, Meg} and Female
```

OWL Manchester Syntax

```
Individual: John
  Types: Father
  Types: hasChild max 4 Parent
  Types: hasChild min 2 Parent
  Types: hasChild exactly 3 Parent
  Types: hasChild exactly 5
  Facts: hasAge "51"^^xsd:integer
  Facts: hasWife Mary
  DifferentFrom: Bill
```

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Class project: final step

- put your corrected DL axioms into your Protege ontology file
- send me the .owl file
- deadline: 3rd of March

- note: this completes two assignments
  - putting ontology into Protege
  - adding the DL axioms

- there will (probably!) be one more project assignment – after the in-class project sessions.

Class project: next week preparation

- **Tuesday 3rd of March and Monday 8th of March.**
- **We will try to do *ontology integration*.**
- **Teams of 2-3 people trying to integrate their ontologies – i.e. make one ontology out of them.**
  - **If we have enough time, we'll integrate them all!**
- **You need to do some preparations for this:**
  - **bring a printout of your ontology (best in Turtle)**
  - **bring an easy to read version (graphical or other) of the main subclass hierarchy of your ontology.**

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Class presentations – scheduled

- RDFa – embedding RDF in HTML (W3C standard)
  Pavan, Thursday 28th of January
- Scalable Distributed Reasoning using MapReduce (Urbani, Kotoulas, Oren, van Harmelen, ISWC2009)
  Wenbo, Thursday 28th of January

- TJ, Security and Semantic Web, 1st of March
- Pramod, Virtuoso, 4th of March
- Hemant, FOAF, 4th of March
- Ashutosh, Linked Open Data, 4th of March
- Prateek, SPARQL, 11th of March
- Vinh, Semantic MediaWiki, 11th of March
- Raghava, DL-Lite, 11th of March

Class Planning

03/01/10: OWL part 4 - Tableaux Calculus + 1 class presentation

03/02/10: class project session

03/04/10: 3 class presentations

03/08/10: class project session

03/09/10: exercise session

03/11/10: 3 class presentations

03/12/10: exams