Knowledge Representation for the Semantic Web

Winter Quarter 2012

Slides 8 – 02/14/2012

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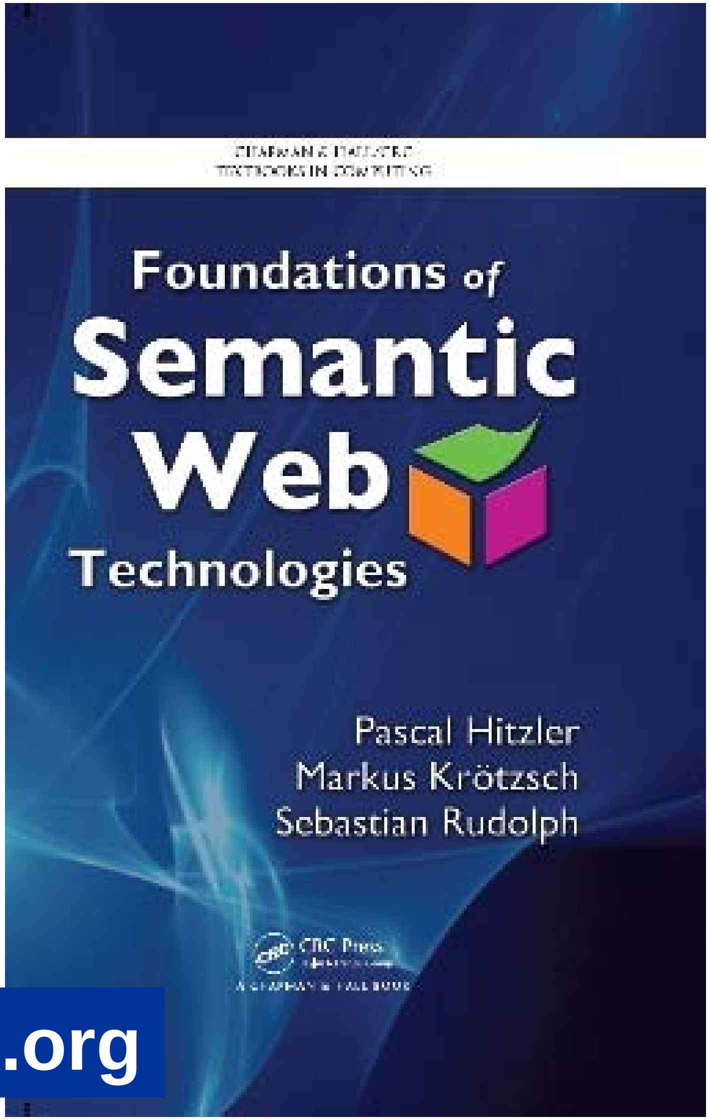
Textbook (required)

Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph

Foundations of Semantic Web Technologies

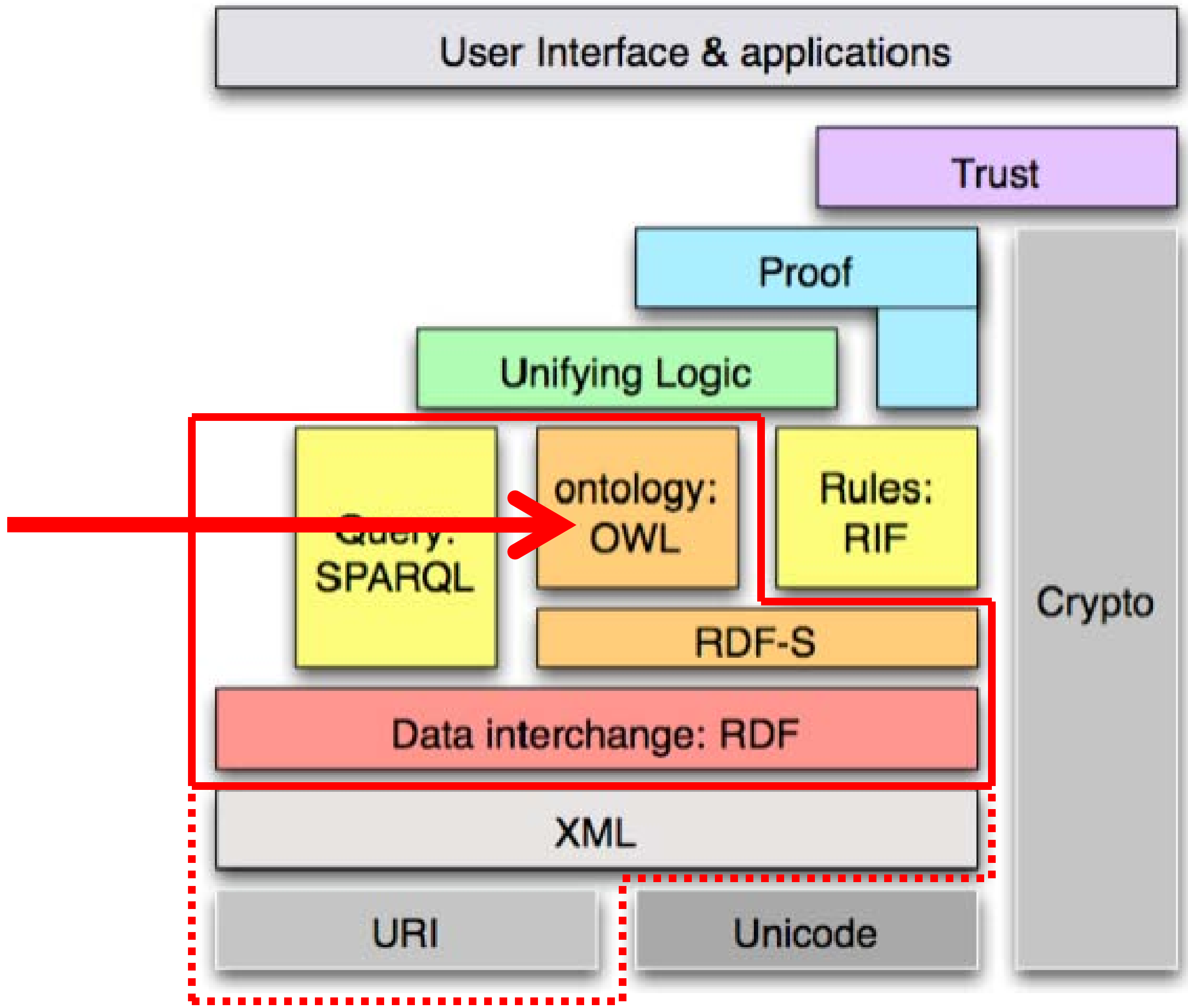
Chapman & Hall/CRC, 2010

Choice Magazine Outstanding Academic Title 2010 (one out of seven in Information & Computer Science)



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 .	Person(mary)
:Mother rdfs:subClassOf :Woman .	Mother $\sqsubseteq$ Woman
:john :hasWife :Mary .	hasWife(john,mary)
:hasWife rdfs:subPropertyOf :hasSpouse	hasWife $\sqsubseteq$ hasSpouse
:hasWife rdfs:range :Woman .	$\top \sqsubseteq \forall$hasWife.Woman
:hasWife rdfs:domain :Man .	$\top \sqsubseteq \forall$hasWife^{-}.Man or $\exists$hasWife.$\top \sqsubseteq$ Man
owl:Thing	$\top$
owl:Nothing	$\bot$
owl:topProperty	U
owl:bottomProperty	*?*

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**

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

into a graph structure?

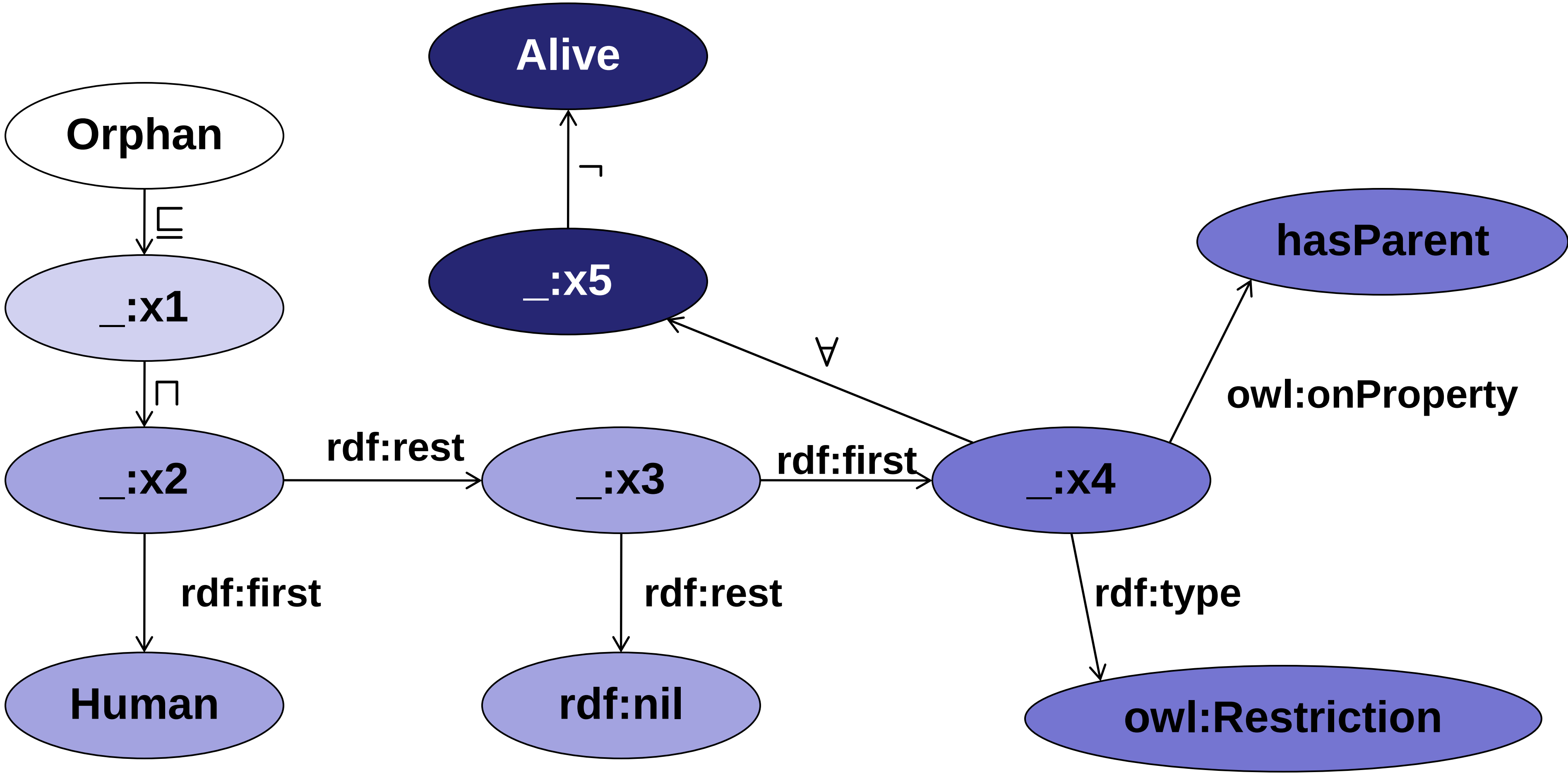
- **How do you do it such that the RDF Schema semantics and the DL semantics are not violated?**

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

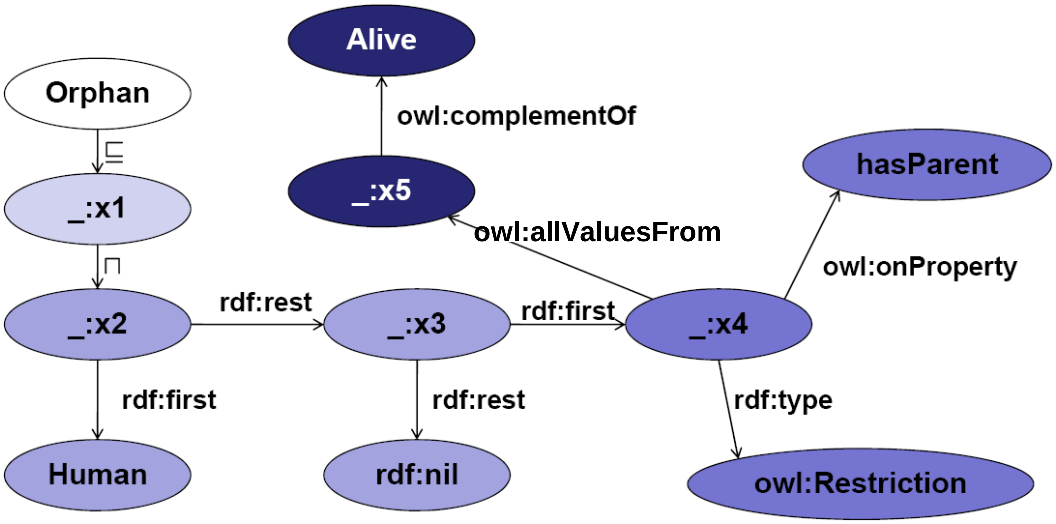
- **That's actually impossible without violating either RDF or DL. We have to do some approximations, and accept that the layering cannot be perfect.**

General Idea

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



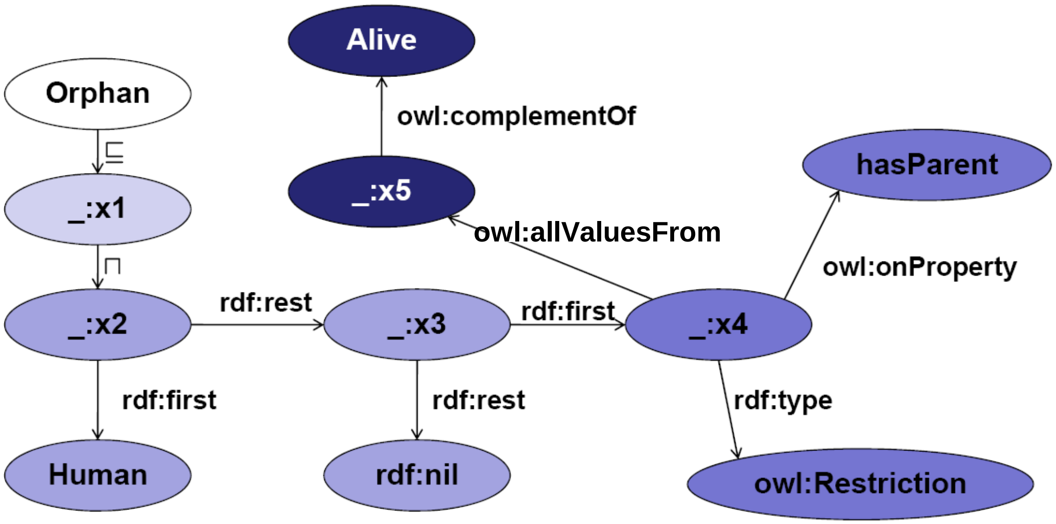
RDF Syntax



- 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 ≡ ∃hasParent.{John}

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

NarcisticPerson ≡ ∃loves.Self

OWL RDF Syntax: Restrictions

≤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
] .
```

≥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.⊤ (John)

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

MyBirthdayGuests ≡ {Bill, John, Mary}

OWL RDF Syntax: Properties

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

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

Orphan ≡ ∀ hasChild^{-}.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`	$\exists y \ldots$	$\exists R.C$
Universal	`owl:allValuesFrom`	$\forall y \ldots$	$\forall R.C$
Min. cardinality	`owl:minQualifiedCardinality` `owl:onClass`	$\exists y1\ldots yn. \ldots$	$\geq n\ S.C$
Max. cardinality	`owl:maxQualifiedCardinality` `owl:onClass`	$\forall y1\ldots yn{+}1. \ldots \rightarrow \ldots$	$\leq n\ S.C$
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:type**	
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

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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++)
  - OWL QL (the description logic DL $Lite_R$)
  - OWL RL (the description logic DLP)
    - 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
      )
    )
  )
)
```

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

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

$Person \sqcap \neg Parent\ (Jack)$

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: next step

- Make sure your ontology is actually in OWL DL (i.e. remove or remodel things which are not in OWL DL).

- Put your OWL ontology into Protégé:

  http://protege.stanford.edu/

- Send the ontology serialized by Protégé (in RDF/XML or Turtle) to me by 19th of February.

Today's Session: OWL Syntax

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Presentation format

- 25 minutes (timing will be strict) plus a few questions
- Content selection is up to you. Presentation must contain the key results from the paper you are presenting. It can also contain material related to these key results which are not in the paper itself (but which you may find more interesting than the rest of the paper).

Presenation evaluation dimensions

Example criteria – may not all be weighted equally:

- **Quality of slides**
- **Quality and effectiveness of explanations**
- **Quality of presentation style (use of verbal and body language, use of media, flexibility in case of interaction with audience, time management)**
- **Correctness of content**
- **Grade of reaching the audience and getting the content across**
- **How “interesting” the material is presented**
- **Competence in answering questions**

Class planning (tentative)

Tuesday 10th of January: RDF Schema
Thursday 12th of January: RDF and RDFS Semantics
Tuesday 17th of January: RDF and RDFS Semantics

Thursday 19th of January: exercise session 1

Tuesday 24th of January: OWL part 1 – Description Logics

Thursday 2nd of February: OWL pt 2 – model-theoretic Semantics

Tuesday 7th of February: Partonomies

Thursday 9th of February: SPARQL

Tuesday 14th of February: OWL part 3 – web syntax

Thursday 16th of February: exercise session 2

Tuesday 21st of February: OWL part 4 – Tableaux calculus

Thursday 23rd of February: Rules

Tuesday 28th of February: exercise session 3