INFO-H-509 XML Technologies
RDF Schema and OWL

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Objectives

1. Ontologies: What and Why
2. RDF Schema syntax and semantics
3. A brief introduction to OWL

Our story so far . . .

Genome

From Wikipedia, the free encyclopedia

For a non-technical introduction to the topic, see Introduction to genetics.

For other uses, see Genome (disambiguation).

In modern molecular biology, the **genome** is the entirety of an organism's hereditary information. It is encoded either in DNA or, for many types of virus, in RNA.

The genome includes both the genes and the non-coding sequences of the DNA.[1] The term was adapted in 1920 by Hans Winkler, Professor of Botany at the University of Hamburg, Germany. The Oxford English Dictionary suggests the name to be a portmanteau of the words ***gen****e* and *chromos****ome***. A few related *-ome* words already existed, such as *biome* and *rhizome*, forming a vocabulary into which *genome* fits systematically.[2]

- Natural language
- No structure
- **Difficult to process automatically**

Our story far . . .

Current – no structure

In modern molecular biology, the **genome** is the entirety of an organism's hereditary information. It is encoded either in DNA or, for many types of virus, in RNA.

The genome includes both the genes and the non-coding sequences of the DNA.[1] The term was adapted in 1920 by Hans Winkler, Professor of Botany at the University of Hamburg, Germany. The Oxford English Dictionary suggests the name to be a portmanteau of the words ***gen****e* and *chromos****ome***. A few related *-ome* words already existed, such as *biome* and *rhizome*, forming a vocabulary into which *genome* fits systematically.[2]

Future – structured by RDF (subject, predicate, object)

```
b:genome    b:field         b:molecular-bio
b:DNA       b:encode        b:genes
b:DNA       b:encode        b:non-coding-seq
b:genome    b:include       b:non-coding-seq
b:genome    b:include       b:gene
b:genome    b:related-to    b:rhizome
```

- RDF is meant to assert knowledge (**statements**) about **entities** (**resources**)
- By convention is clear what the **subject**, **predicate**, and **object** are
- Easier to process automatically, but a computer still does not know their meaning . . .
- Can we add some **semantics** to the statements?

What do you mean: Semantics?

Input

```
@prefix prod: <http://www.example.org/products/> .
@prefix terms: <http://www.example.org/terms/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
prod:cam1    rdf:type      terms:digital-camera   .
prod:cam1    terms:price   150                    .
prod:nb1     rdf:type      terms:netbook          .
prod:nb1     terms:price   300                    .
prod:book1   rdf:type      terms:book             .
prod:book1   terms:price   2.50                   .
```

How do we find all products that are digital devices?

What do you mean: Semantics?

Input

```
@prefix prod: <http://www.example.org/products/> .
@prefix terms: <http://www.example.org/terms/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
prod:cam1    rdf:type      terms:digital-camera   .
prod:cam1    terms:price   150                    .
prod:nb1     rdf:type      terms:netbook          .
prod:nb1     terms:price   300                    .
prod:book1   rdf:type      terms:book             .
prod:book1   terms:price   2.50                   .
```

How do we find all products that are digital devices?

```
PREFIX prod: <http://www.example.org/products/>
PREFIX terms: <http://www.example.org/terms/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

SELECT ?prod
WHERE {
     { ?prod rdf:type terms:digital-camera .}
     UNION
     { ?prod rdf:type terms:netbook .}
}
```

What do you mean: Semantics?

Input

```
@prefix prod: <http://www.example.org/products/> .
@prefix terms: <http://www.example.org/terms/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
prod:cam1    rdf:type      terms:digital-camera   .
prod:cam1    terms:price   150                    .
prod:nb1     rdf:type      terms:netbook          .
prod:nb1     terms:price   300                    .
prod:book1   rdf:type      terms:book             .
prod:book1   terms:price   2.50                   .
```

- The computer has no "knowledge of the world" stating that cameras and netbooks are digital devices
- So we have to manually encode this "knowledge of the world" in the query
- This solution is inadequate: error-prone and difficult to maintain
- **It would be better if we could tell the computer our "knowledge of the world" and let him do the reasoning!**

Reasoning by means of Inference: the General Idea

Explicitly Asserted Knowledge

I am a man
John is a man
Jane is a woman

Reasoning by means of Inference: the General Idea

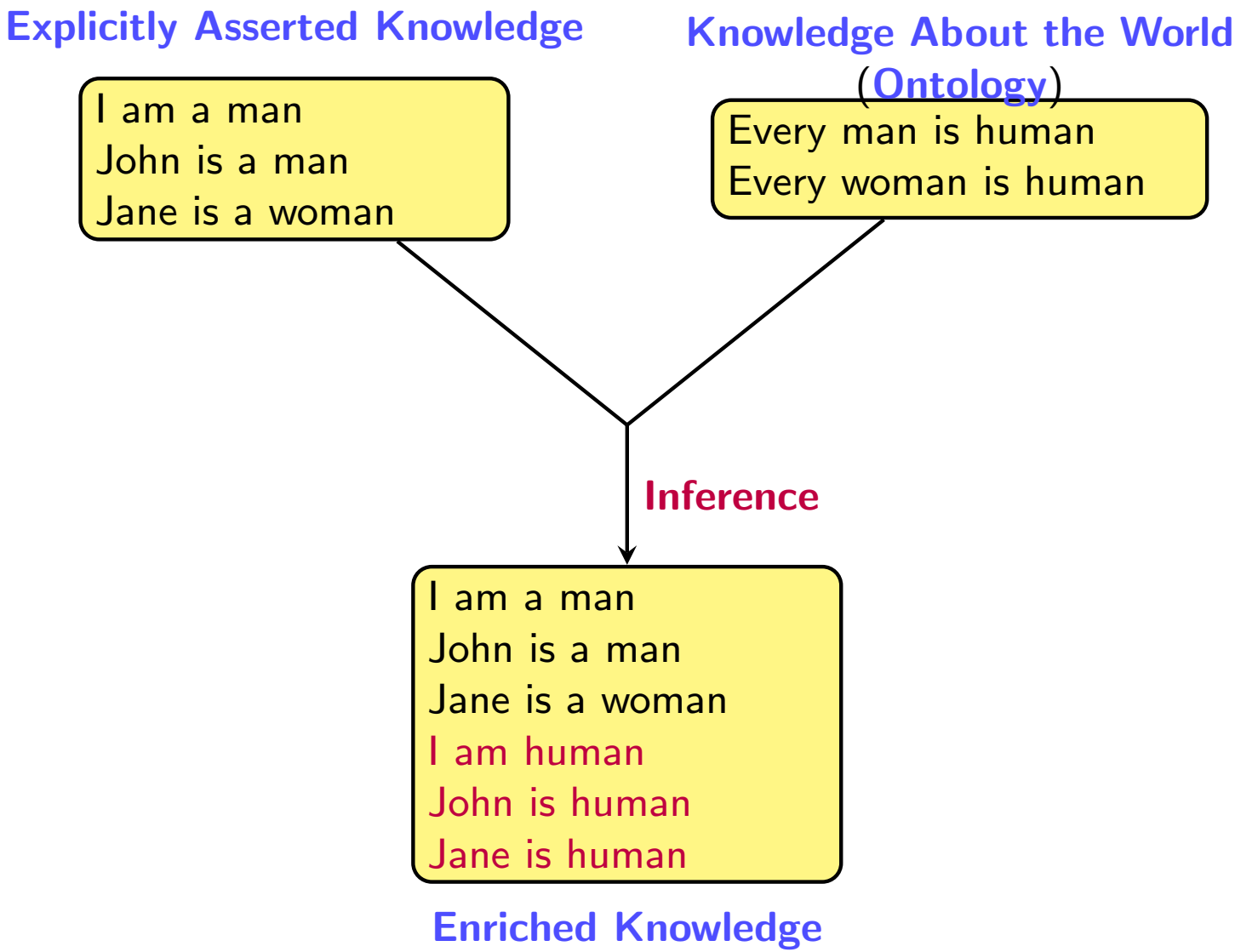
Explicitly Asserted Knowledge

I am a man
John is a man
Jane is a woman

Knowledge About the World (Ontology)

Every man is human
Every woman is human

Reasoning by means of Inference: the General Idea



Towards a Smarter Web

"Knowledge about the world" for our example:

- Every camera is a digital device
- Every netbook is a digital device
- Every computer is a digital device
- Every book is human-readable

Such knowledge is set-based (also called class-based)

- The set of cameras is a subset of the set of digital devices
- The set of netbooks is a subset of the set of digital devices
- The set of books is a subset of the set of human-readable objects

Definition

Ontologies (sometimes also called Schemas or Vocabularies) provide formal specifications of the **classes of objects** that inhabit "the world", the relationships between classes, and their properties.

Reasoning by means of Inference: the General Idea (2)

Explicitly Asserted Knowledge

prod:cam1	rdf:type	terms:digital-camera
prod:cam1	terms:price	150
prod:nb1	rdf:type	terms:netbook
prod:nb1	terms:price	300
prod:book1	rdf:type	terms:book
prod:book1	terms:price	2.50

Reasoning by means of Inference: the General Idea (2)

Explicitly Asserted Knowledge

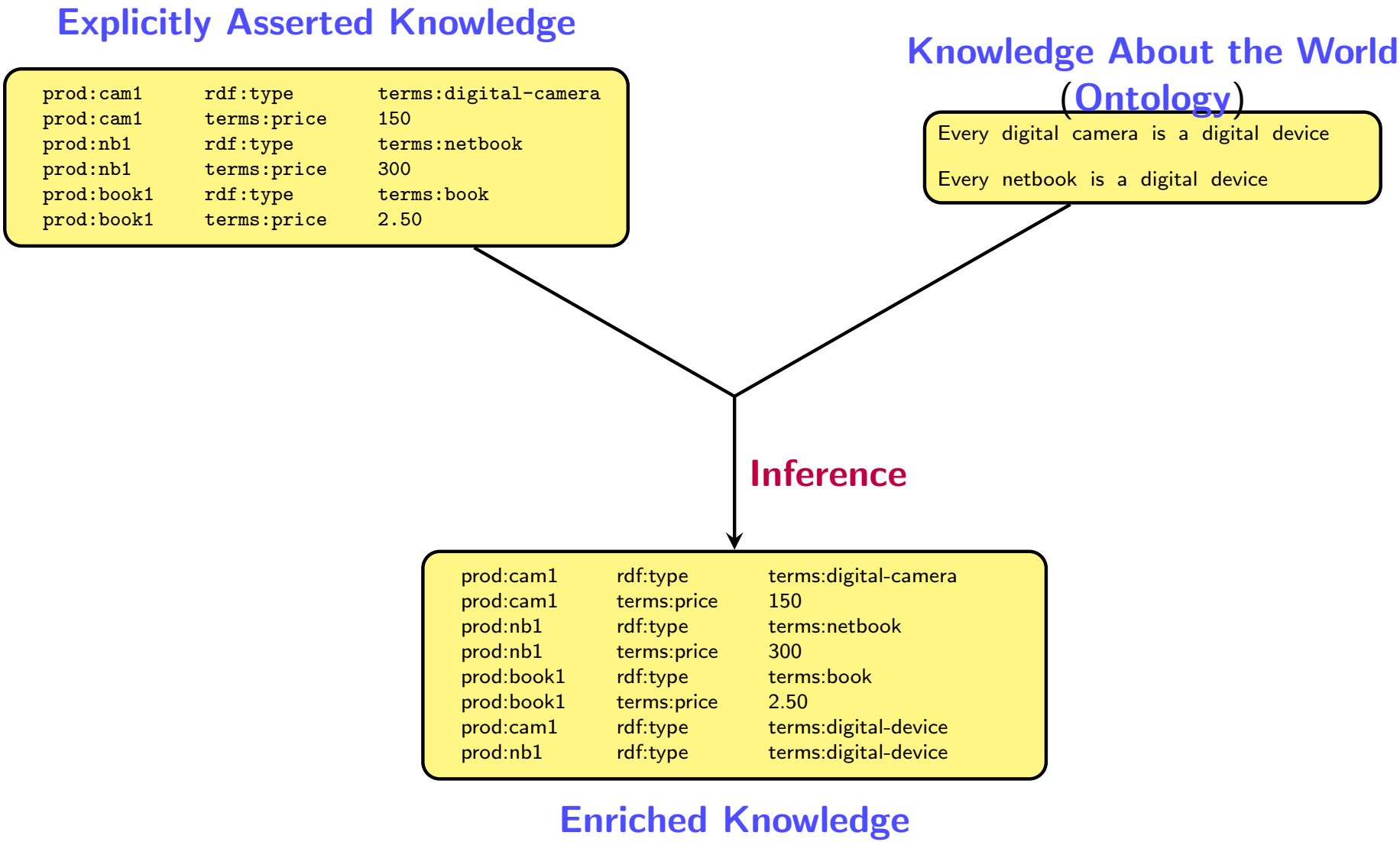
prod:cam1	rdf:type	terms:digital-camera
prod:cam1	terms:price	150
prod:nb1	rdf:type	terms:netbook
prod:nb1	terms:price	300
prod:book1	rdf:type	terms:book
prod:book1	terms:price	2.50

Knowledge About the World (Ontology)

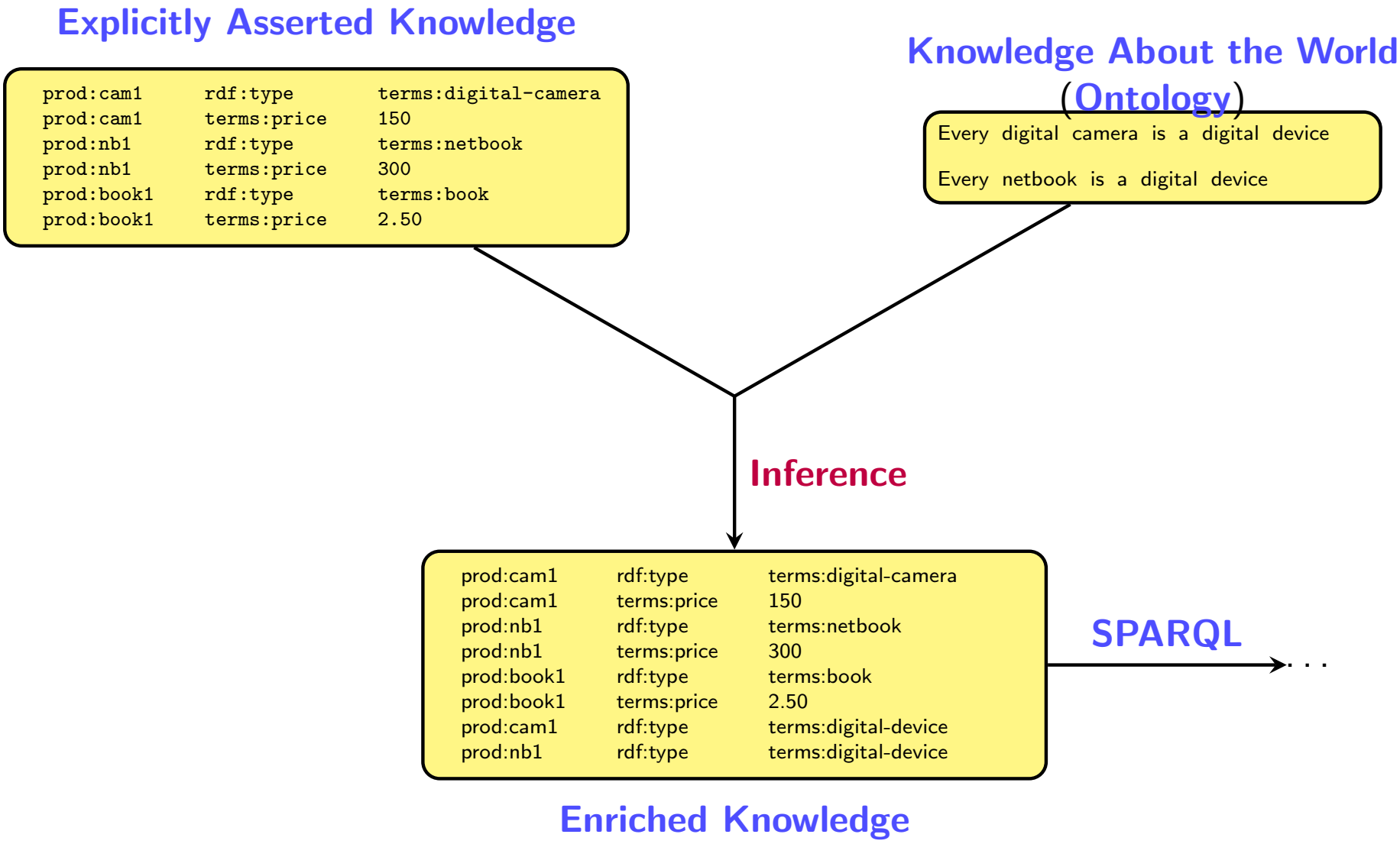
Every digital camera is a digital device

Every netbook is a digital device

Reasoning by means of Inference: the General Idea (2)



Reasoning by means of Inference: the General Idea (2)



RDF Schema and OWL

How do we specify ontologies?

- RDF Schema and the Ontology Web Language (OWL) allow ontologies to be specified **in RDF itself**: they provide resources and properties in a **standard namespace** to talk about class relationships, properties of classes, ...
- They also specify how these resources and properties should be interpreted (in terms of inference)
- OWL allows more fine-grained knowledge of the world to be specified, at the cost of less efficient inference and reasoning

Example:

```
@prefix terms: <http://www.example.org/terms/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

terms:digital-camera      rdfs:subClassOf   terms:digital-device .
terms:netbook             rdfs:subClassOf   terms:digital-device .
terms:book                rdfs:subClassOf   terms:media .
terms:digital-device      rdfs:subClassOf   terms:electronic-device .
terms:electronic-device   rdfs:subClassOf   terms:device .
```

RDF Schema and OWL

Example Ontology in RDF Schema:

```
@prefix terms: <http://www.example.org/terms/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

terms:digital-camera   rdfs:subClassOf   terms:digital-device .
terms:netbook          rdfs:subClassOf   terms:digital-device .
terms:book             rdfs:subClassOf   terms:media .
```

Starting from the following asserted triples . . .

```
@prefix prod: <http://www.example.org/products/> .
@prefix terms: <http://www.example.org/terms/>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
prod:cam1     rdf:type      terms:digital-camera    .
prod:cam1     terms:price   150                     .
prod:nb1      rdf:type      terms:netbook           .
prod:nb1      terms:price   300                     .
prod:book1    rdf:type      terms:book              .
prod:book1    terms:price   2.50                    .
```

RDF Schema and OWL

Example Ontology in RDF Schema:

```
@prefix terms: <http://www.example.org/terms/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

terms:digital-camera   rdfs:subClassOf   terms:digital-device .
terms:netbook          rdfs:subClassOf   terms:digital-device .
terms:book             rdfs:subClassOf   terms:media .
```

. . . an RDF Schema-aware processor will infer the following triples (in purple)

```
@prefix prod: <http://www.example.org/products/> .
@prefix terms: <http://www.example.org/terms/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
prod:cam1     rdf:type      terms:digital-camera    .
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prod:book1    rdf:type      terms:book              .
prod:book1    terms:price   2.50                    .
prod:cam1     rdf:type      terms:digital-device    .
prod:nb1      rdf:type      terms:digital-device    .
prod:book1    rdf:type      terms:media             .
```

RDF Schema and OWL

Example Ontology in RDF Schema:

```
@prefix terms: <http://www.example.org/terms/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

terms:digital-camera   rdfs:subClassOf   terms:digital-device .
terms:netbook          rdfs:subClassOf   terms:digital-device .
terms:book             rdfs:subClassOf   terms:media .
```

So finding all products that are digital devices becomes easy (assuming our SPARQL engine is RDFS-aware):

```
PREFIX prod: <http://www.example.org/products/>
PREFIX terms: <http://www.example.org/terms/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

SELECT ?prod
WHERE {
      ?prod rdf:type terms:digital-device .
}
```

Part I: RDF Schema

Diving right in: `rdfs:subClassOf`

- Like all RDF Schema resources and properties, `subClassOf` lives in the namespace `http://www.w3.org/1999/02/22-rdf-syntax-ns#`
- `X rdfs:subClassOf Y` is used to specify that all members of a class X are also members of a class Y

Inference Rule [I-SUBCLASS]

If	`?A rdfs:subClassOf ?B .`
And	`?x rdf:type ?A .`
Then add	`?x rdf:type ?B .`

Example

:C1	rdfs:subClassOf	:C2 .
:C2	rdfs:subClassOf	:C3 .
:x	rdf:type	:C1 .

Diving right in: `rdfs:subClassOf`

- Like all RDF Schema resources and properties, `subClassOf` lives in the namespace `http://www.w3.org/1999/02/22-rdf-syntax-ns#`
- `X rdfs:subClassOf Y` is used to specify that all members of a class X are also members of a class Y

Inference Rule [I-SUBCLASS]

If	`?A rdfs:subClassOf ?B .`
And	`?x rdf:type ?A .`
Then add	`?x rdf:type ?B .`

Example

:C1	rdfs:subClassOf	:C2 .
:C2	rdfs:subClassOf	:C3 .
:x	rdf:type	:C1 .
:x	rdf:type	:C2 .

Diving right in: `rdfs:subClassOf`

- Like all RDF Schema resources and properties, `subClassOf` lives in the namespace `http://www.w3.org/1999/02/22-rdf-syntax-ns#`
- `X rdfs:subClassOf Y` is used to specify that all members of a class X are also members of a class Y

Inference Rule [I-SUBCLASS]

If	`?A rdfs:subClassOf ?B .`
And	`?x rdf:type ?A .`
Then add	`?x rdf:type ?B .`

Example

:C1	rdfs:subClassOf	:C2 .
:C2	rdfs:subClassOf	:C3 .
:x	rdf:type	:C1 .
:x	rdf:type	:C2 .
:x	rdf:type	:C3 .

Diving right in: `rdfs:subPropertyOf`

- `X rdfs:subPropertyOf Y` is used to specify that all resources with property X also have property Y

Inference Rule [I-SUBPROP]

If	`?P rdfs:subPropertyOf ?R .`
And	`?x ?P ?y .`
Then add	`?x ?R ?y .`

Example

:P	rdfs:subPropertyOf	:R .
:John	:P	:o1 .

Diving right in: `rdfs:subPropertyOf`

- `X rdfs:subPropertyOf Y` is used to specify that all resources with property X also have property Y

Inference Rule [I-SUBPROP]

If	`?P rdfs:subPropertyOf ?R .`
And	`?x ?P ?y .`
Then add	`?x ?R ?y .`

Example

:P	rdfs:subPropertyOf	:R .
:John	:P	:o1 .
:John	:R	:o1 .

Diving right in: `rdfs:domain`

- `P rdfs:domain C` is used to specify that all resources with outgoing property P belong to class C

Inference Rule [I-DOMAIN]

If	`?P rdfs:domain ?C .`
And	`?x ?P ?y .`
Then add	`?x rdf:type ?C .`

Example

:P	rdfs:domain	:C1 .
:John	:P	:o1 .

Diving right in: `rdfs:domain`

- `P rdfs:domain C` is used to specify that all resources with outgoing property *P* belong to class *C*

Inference Rule [I-DOMAIN]

If	`?P rdfs:domain ?C .`
And	`?x ?P ?y .`
Then add	`?x rdf:type ?C .`

Example

:P	rdfs:domain	:C1 .
:John	:P	:o1 .
:John	rdf:type	:C1 .

Interaction of Rules

Consider the following example. What new triples are inferred?

```
:MarriedWoman    rdfs:subClassOf    :Woman          .
:maidenName      rdfs:domain        :MarriedWoman   .

:Karen           :maidenName        "Stephens"      .
```

Interaction of Rules

Consider the following example. What new triples are inferred?

:MarriedWoman	rdfs:subClassOf	:Woman	.
:maidenName	rdfs:domain	:MarriedWoman	.
:Karen	:maidenName	"Stephens"	.
:Karen	rdf:type	:MarriedWoman	.

Interaction of Rules

Consider the following example. What new triples are inferred?

:MarriedWoman	rdfs:subClassOf	:Woman	.
:maidenName	rdfs:domain	:MarriedWoman	.
:Karen	:maidenName	"Stephens"	.
:Karen	rdf:type	:MarriedWoman	.
:Karen	rdf:type	:Woman	.

Interaction of Rules

Consider the following example. What new triples are inferred?

:MarriedWoman	rdfs:subClassOf	:Woman .
:maidenName	rdfs:domain	:MarriedWoman .
:Karen	:maidenName	"Stephens" .
:Karen	rdf:type	:MarriedWoman .
:Karen	rdf:type	:Woman .

This illustrates the following effect

Inference Rule [Interaction-1]

If	`?P rdfs:domain ?D .`
And	`?D rdfs:subClassOf ?C .`
Then add	`?P rdfs:domain ?C .`

Diving right in: `rdfs:range`

- `P rdfs:range C` is used to specify that all resources with incoming property *P* belong to class *C*

Inference Rule [I-RANGE]

If	`?P rdfs:range ?C .`
And	`?x ?P ?y .`
Then add	`?y rdf:type ?C .`

Example

:P	rdfs:domain	:C1 .
:P	rdfs:range	:C2 .
:John	:P	:o1 .

Diving right in: `rdfs:range`

- `P rdfs:range C` is used to specify that all resources with incoming property *P* belong to class *C*

Inference Rule [I-RANGE]

If	`?P rdfs:range ?C .`
And	`?x ?P ?y .`
Then add	`?y rdf:type ?C .`

Example

:P	rdfs:domain	:C1 .
:P	rdfs:range	:C2 .
:John	:P	:o1 .
:John	rdf:type	:C1 .
:o1	rdf:type	:C2 .

Meta-Concepts

RDF Schema also provides the following resources:

- `rdfs:Resource` — The class of all resources. Every resource is an instance of this class
- `rdfs:Class` — The class of all classes.
- `rdfs:Literal` — The class of all literals.
- `rdfs:Property` — The class of all properties.
- `rdfs:Datatype` — The class of all datatypes.

RDF Schema is equipped with the following built-in triples (among others)

```
rdfs:subClassOf      rdfs:domain       rdfs:Class    .
rdfs:subClassOf      rdfs:range        rdfs:Class    .
rdfs:subClassOf      rdf:type          rdfs:Property .
rdfs:subPropertyOf   rdfs:domain       rdfs:Property .
rdfs:subPropertyOf   rdfs:range        rdfs:Property .
rdfs:subPropertyOf   rdf:type          rdfs:Property .
rdfs:domain          rdf:type          rdfs:Property .
rdfs:range           rdf:type          rdfs:Property .
rdfs:Resource        rdf:type          rdfs:Class    .
rdfs:Class           rdfs:subClassOf   rdfs:Resource .
```

Part II: OWL

Limitations of RDF Schema

RDF Schema allows us to represent **some** ontological knowledge:

- Typed hierarchies using classes and subclasses, properties and subproperties
- Domain and range restrictions
- Describing instances of classes (through subclasses and `rdf:type`)

Sometimes we want more:

- **Local scope of properties** Using `rdfs:range` and `rdfs:domain` we can't state that cows only eat plants while other animals may eat meat too.
- **Disjointness of classes**. We can't state, for example, that `terms:male` and `terms:female` do not have any members in common.
- **Special characteristics of properties**. Sometimes it is convenient to be able to say that a property is **transitive** (like "greater than"), **unique** (like "father of"), or the **inverse** of another property (like "father of" and "child of").
- **Cardinality restrictions** like "a person has exactly 2 parents"

OWL: Ontology Web Language

The **Ontology Web Language (OWL)** allows us to talk about such things (among others)

OWL: Ontology Web Language

The **Ontology Web Language (OWL)** allows us to talk about such things (among others)

There is always a trade-off between expressiveness and efficient reasoning support:

- The more expressive a language ...
- The more inefficient the inferincing becomes ...
- ... it may even become **undecidable**!

OWL: Ontology Web Language

There are actually 3 OWL sublanguages:

- **OWL Full**: all features, but undecidable
- **OWL DL**[a]: expressive, but not entirely compatible with RDF Schema; efficient reasoning support
- **OWL Lite**: the least expressive, but compatible with RDF Schema; efficient reasoning support

[a] DL=Description Logic

Here, we will illustrate some features of OWL Lite

Special Characteristics of Properties: Inverses

- All OWL resources and properties live in the namespace `http://www.w3.org/2002/07/owl#`
- `P owl:inverseOf R` is used to specify that property R is the inverse of property P (and vice versa)

Inference Rule [I-INVERSE]

```
If        ?P owl:inverseOf ?R .
And       ?x ?P ?y .
Then add  ?y ?R ?x .

If        ?P owl:inverseOf ?R .
And       ?x ?R ?y .
Then add  ?y ?P ?x .
```

Example

```
:fatherOf   owl:inverseOf   :childOf .
:Jake       :fatherOf       :John    .
```

Special Characteristics of Properties: Inverses

- All OWL resources and properties live in the namespace `http://www.w3.org/2002/07/owl#`
- `P owl:inverseOf R` is used to specify that property R is the inverse of property P (and vice versa)

Inference Rule [I-INVERSE]

If	`?P owl:inverseOf ?R .`
And	`?x ?P ?y .`
Then add	`?y ?R ?x .`
If	`?P owl:inverseOf ?R .`
And	`?x ?R ?y .`
Then add	`?y ?P ?x .`

Example

:fatherOf	owl:inverseOf	:childOf .
:Jake	:fatherOf	:John .
:John	:childOf	:Jake .

Special Characteristics of Properties: Symmetry

- `P rdf:type owl:SymmetricProperty` is used to specify that property P is a symmetric property

Inference Rule [I-SYMMETRIC]

If	`?P rdf:type owl:SymmetricProperty .`
And	`?x ?P ?y .`
Then add	`?y ?P ?x .`

Example

:marriedTo	rdf:type	owl:SymmetricProperty	.
:Jake	:marriedTo	:Eve	.

Special Characteristics of Properties: Symmetry

- `P rdf:type owl:SymmetricProperty` is used to specify that property P is a symmetric property

Inference Rule [I-SYMMETRIC]

If	`?P rdf:type owl:SymmetricProperty .`
And	`?x ?P ?y .`
Then add	`?y ?P ?x .`

Example

:marriedTo	rdf:type	owl:SymmetricProperty	.
:Jake	:marriedTo	:Eve	.
:Eve	:marriedTo	:Jake	.

Special Characteristics of Properties: Transitivity

- `P rdf:type owl:TransitiveProperty` is used to specify that property P is a Transitive property

Inference Rule [I-TRANSITIVE]

If	`?P rdf:type owl:TransitiveProperty .`
And	`?x ?P ?y .`
And	`?y ?P ?z .`
Then add	`?x ?P ?z .`

Example

:ancestor	rdf:type	owl:TransitiveProperty	.
:Jake	:ancestor	:John	.
:Jill	:ancestor	:Jake	.

Special Characteristics of Properties: Transitivity

- `P rdf:type owl:TransitiveProperty` is used to specify that property P is a Transitive property

Inference Rule [I-TRANSITIVE]

If	`?P rdf:type owl:TransitiveProperty .`
And	`?x ?P ?y .`
And	`?y ?P ?z .`
Then add	`?x ?P ?z .`

Example

:ancestor	rdf:type	owl:TransitiveProperty	.
:Jake	:ancestor	:John	.
:Jill	:ancestor	:Jake	.
:Jill	:ancestor	:John	.

Asserting Equivalence of Classes

- It is always possible that we have used a specific URI to identify a particular concept while someone else has used a different URI for the same concept
- `C owl:equivalentClass D` is used to specify that every member of class C is a member of class D, and vice versa

Semantics is given by

```
owl:equivalentClass rdf:type owl:SymmetricProperty .
owl:equivalentClass rdf:type owl:TransitiveProperty .
owl:equivalentClass rdfs:subPropertyOf rdfs:subClassOf .
```

Example

```
:Man    owl:equivalentClass    :Homme .
:Jake   rdf:type               :Man   .
```

Asserting Equivalence of Classes

- It is always possible that we have used a specific URI to identify a particular concept while someone else has used a different URI for the same concept
- `C owl:equivalentClass D` is used to specify that every member of class C is a member of class D, and vice versa

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```
owl:equivalentClass rdf:type owl:SymmetricProperty .
owl:equivalentClass rdf:type owl:TransitiveProperty .
owl:equivalentClass rdfs:subPropertyOf rdfs:subClassOf .
```

Example

:Man	owl:equivalentClass	:Homme .
:Jake	rdf:type	:Man .
:Homme	owl:equivalentclass	:Man .
:Man	rdfs:subClassOf	:Homme .
:Homme	rdfs:subClassOf	:Man .
:Jake	rdf:type	:Homme .

Asserting Equivalence of Predicates

- It is always possible that we have used a specific URI to identify a particular concept while someone else has used a different URI for the same concept
- `P owl:equivalentProperty R` is used to specify that properties P and R are equivalent

Semantics is given by

```
owl:equivalentProperty rdf:type owl:SymmetricProperty .
owl:equivalentProperty rdf:type owl:TransitiveProperty .
owl:equivalentProperty rdfs:subPropertyOf rdfs:subPropertyOf .
```

```
:fatherOf    owl:equivalentProperty    :père  .
:Jake        :père                     :John  .
```

Asserting Equivalence of Predicates

- It is always possible that we have used a specific URI to identify a particular concept while someone else has used a different URI for the same concept
- `P owl:equivalentProperty R` is used to specify that properties P and R are equivalent

Semantics is given by

```
owl:equivalentProperty rdf:type owl:SymmetricProperty .
owl:equivalentProperty rdf:type owl:TransitiveProperty .
owl:equivalentProperty rdfs:subPropertyOf rdfs:subPropertyOf .
```

:fatherOf	owl:equivalentProperty	:père	.
:Jake	:père	:John	.
:père	owl:equivalentProperty	:fatherOf	.
:père	rdfs:subPropertyOf	:fatherOf	.
:fatherOf	rdfs:subPropertyOf	:père	.
:Jake	:fatherOf	:John	.

Asserting Equivalence of Resources

- It is always possible that we have used a specific URI to identify a particular concept while someone else has used a different URI for the same concept
- `x owl:sameAs x` is used to specify that x and y are the same resources

Semantics is given by

```
owl:sameAs rdf:type owl:SymmetricProperty .

If        ?x owl:sameAs ?y .
And       ?x ?P ?z .
Then add  ?y ?P ?z .

If        ?x owl:sameAs ?y .
And       ?z ?P ?x .
Then add  ?z ?P ?y .
```

Functional Properties

- `P rdf:type owl:FunctionalProperty` is used to specify that P can only take one object for a particular subject

Inference Rule:

If	`?P rdf:type owl:FunctionalProperty .`
And	`?x ?P ?y .`
And	`?x ?P ?z .`
Then add	`?y owl:sameAs ?z .`

Example

:hasFather	rdf:type	owl:FunctionalProperty	.
:John	:hasFather	:Jake	.
:John	:hasFather	ex:Jake-J	.

Functional Properties

- `P rdf:type owl:FunctionalProperty` is used to specify that P can only take one object for a particular subject

Inference Rule:

If	`?P rdf:type owl:FunctionalProperty .`
And	`?x ?P ?y .`
And	`?x ?P ?z .`
Then add	`?y owl:sameAs ?z .`

Example

:hasFather	rdf:type	owl:FunctionalProperty	.
:John	:hasFather	:Jake	.
:John	:hasFather	ex:Jake-J	.
:Jake	owl:sameAs	ex:Jake-J	.

Inverse Functional Properties

- `P rdf:type owl:InverseFunctionalProperty` is used to specify that P can only take one subject for a particular object

Inference Rule:

```
If        ?P rdf:type owl:InverseFunctionalProperty .
And       ?y ?P ?x .
And       ?z ?P ?x .
Then add  ?y owl:sameAs ?z .
```