CC6202-1
La Web de Datos
Primavera 2016

Lecture 3: RDF Semantics and Schema

Aidan Hogan
aidhog@gmail.com

LAST TIME …

(1) Data, (2) Rules/Ontologies, (3) Query,

INPUT: "$(x$,partOf,$y)$"

DATA:

`http://ex.org/Ireland`

Ireland 

(Ireland,partOf,Europe)
(Ireland,a,Country)
(Ireland,capital,Dublin)

`http://ex.org/Dublin`

Dublin 

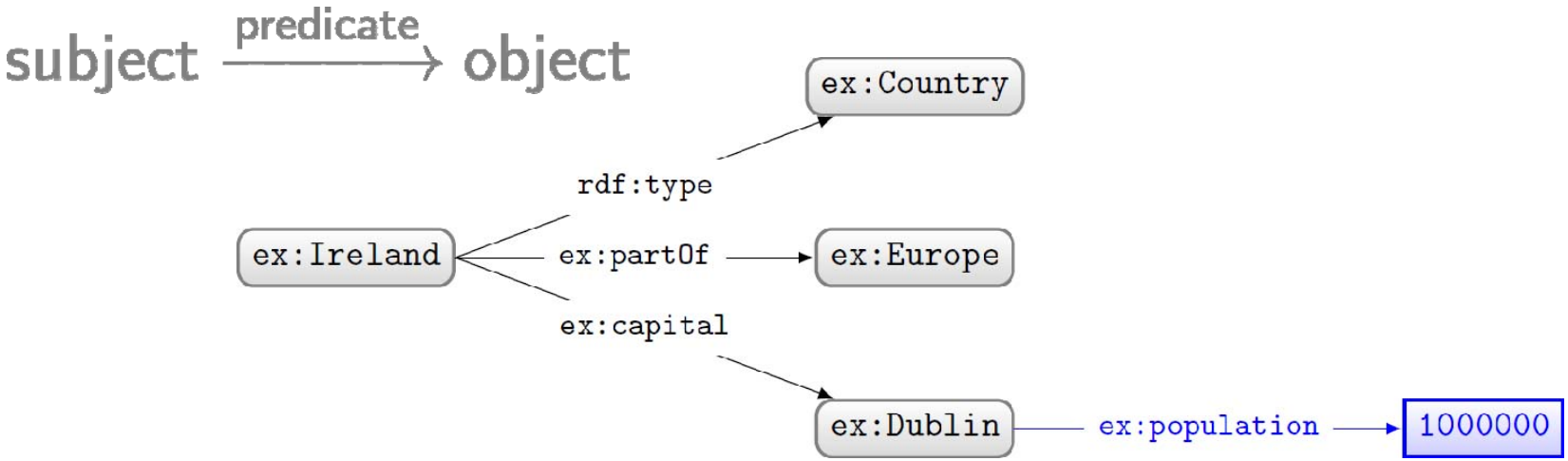
(Dublin,population,1000000)

RULES: $(a, \text{capital}, b) \rightarrow (b, \text{partOf}, a)$
$(c, \text{partOf}, d), (d, \text{partOf}, e) \rightarrow (c, \text{partOf}, e)$

OUTPUT: $\{(x \mapsto \text{Ireland}, y \mapsto \text{Europe}), (x \mapsto \text{Dublin}, y \mapsto \text{Ireland})$
$(x \mapsto \text{Dublin}, y \mapsto \text{Europe})\}$

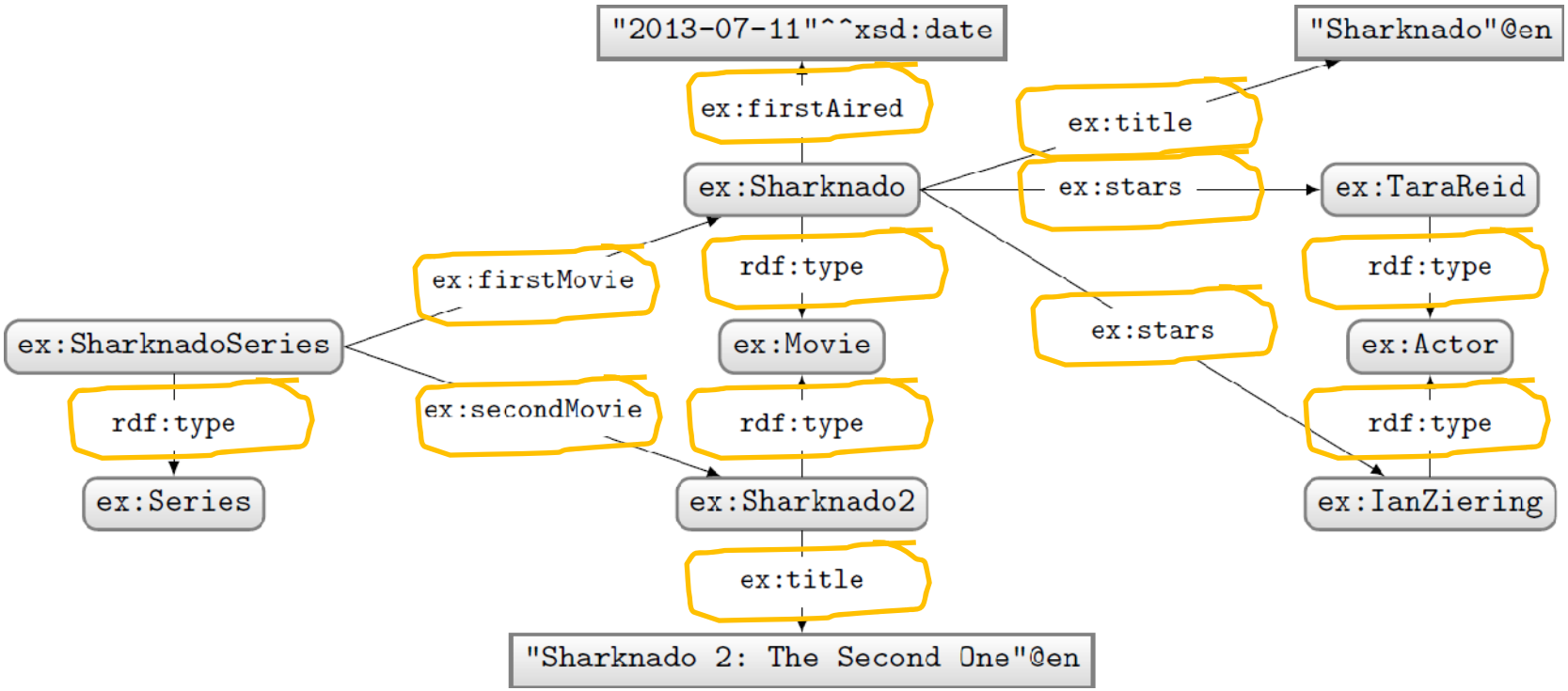
RDF: Resource Description Framework

subject	*predicate*	*object*
ex:Ireland	ex:partOf	ex:Europe
ex:Ireland	rdf:type	ex:Country
ex:Ireland	ex:capital	ex:Dublin
ex:Dublin	ex:population	1,000,000



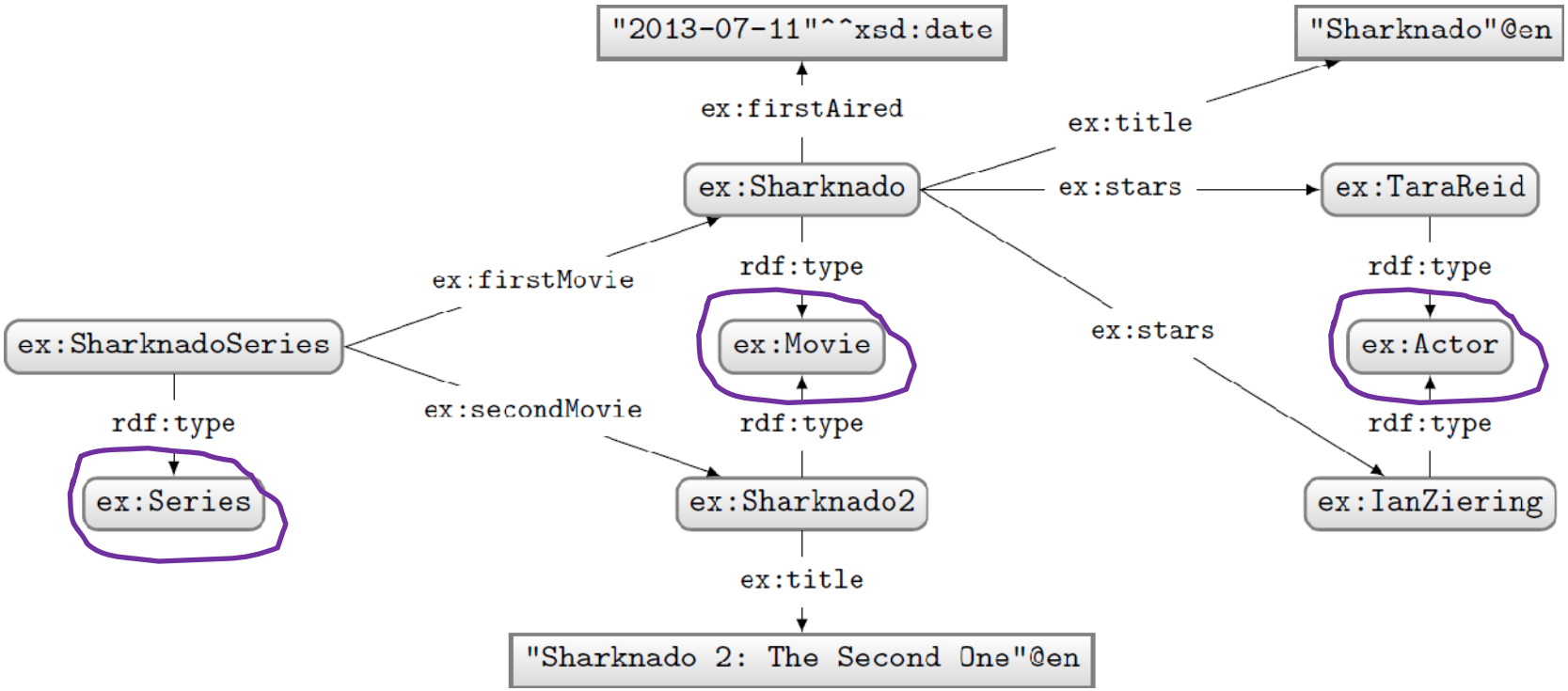
RDF Properties

- RDF Terms used as predicate
- `rdf:type`, `ex:firstMovie`, `ex:stars`, …



RDF Classes

- Used to conceptually group resources
- The predicate `rdf:type` is used to relate resources to their classes



TODAY’S TOPIC …

(1) Data, **(2) Rules/Ontologies,** (3) Query

INPUT: "(x,partOf,y)"

DATA:

`http://ex.org/Ireland`

Ireland 

(Ireland,partOf,Europe)
(Ireland,a,Country)
(Ireland,capital,Dublin)

`http://ex.org/Dublin`

Dublin 

(Dublin,population,1000000)

RULES: $(a, \text{capital}, b) \rightarrow (b, \text{partOf}, a)$
$(c, \text{partOf}, d), (d, \text{partOf}, e) \rightarrow (c, \text{partOf}, e)$

OUTPUT: $\{(x \mapsto \text{Ireland}, y \mapsto \text{Europe}), (x \mapsto \text{Dublin}, y \mapsto \text{Ireland})$
$(x \mapsto \text{Dublin}, y \mapsto \text{Europe})\}$

How to structure “rules”?

- How to write them down?
- Where to publish them?

How should we structure
rules on the Semantic Web?

RULES: $(a, \mathsf{capital}, b) \rightarrow (b, \mathsf{partOf}, a)$
$(c, \mathsf{partOf}, d), (d, \mathsf{partOf}, e) \rightarrow (c, \mathsf{partOf}, e)$

Semantic Web Answer: Schema/Ontologies

- Don't use rules: Use RDF!
- Define relationships between classes and properties

What sorts of relationships might be useful to define between the following classes and properties?

ex:Town

ex:hasCapitalCity

ex:hasCity

ex:City

ex:Country

foaf:familyName

ex:Place

foaf:Person

ex:geographicallyPartOf

ex:CapitalCity

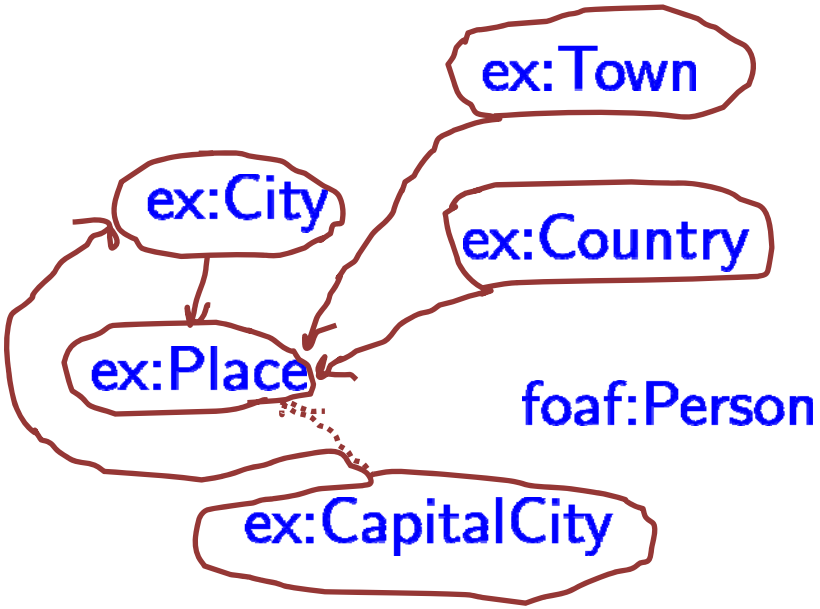
ex:partOf

Class hierarchy

- Class *c1* is a sub-class of Class *c2*
  - If (x,rdf:type,*c1*) then (x,rdf:type,*c2*),

Example: if ex:CapitalCity *sub-class of* ex:City
and if (ex:Dublin,rdf:type,ex:CapitalCity)
then (ex:Dublin,rdf:type,ex:City)

Which classes would be sub-classes of each other?

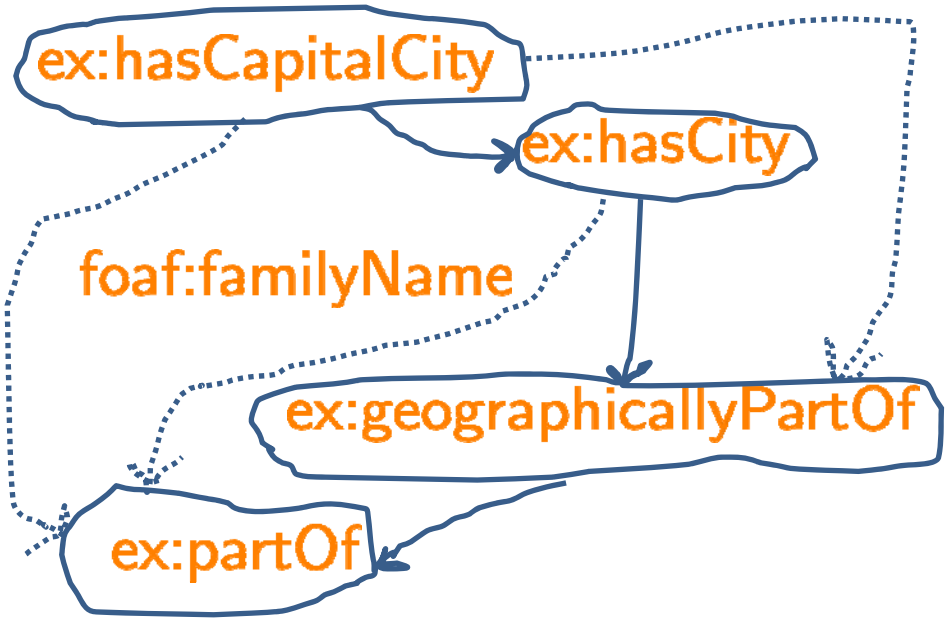


Property hierarchy

- Property *p1* is a sub-property of *p2*
  - If (x,*p1*,y) then (x,*p2*,y)

Example: if `ex:hasCapitalCity` *sub-property of* `ex:hasCity`
and if `(ex:Ireland,ex:hasCapitalCity,ex:Dublin)`
then `(ex:Ireland,ex:hasCity,ex:Dublin)`

Which properties would be sub-properties of each other?

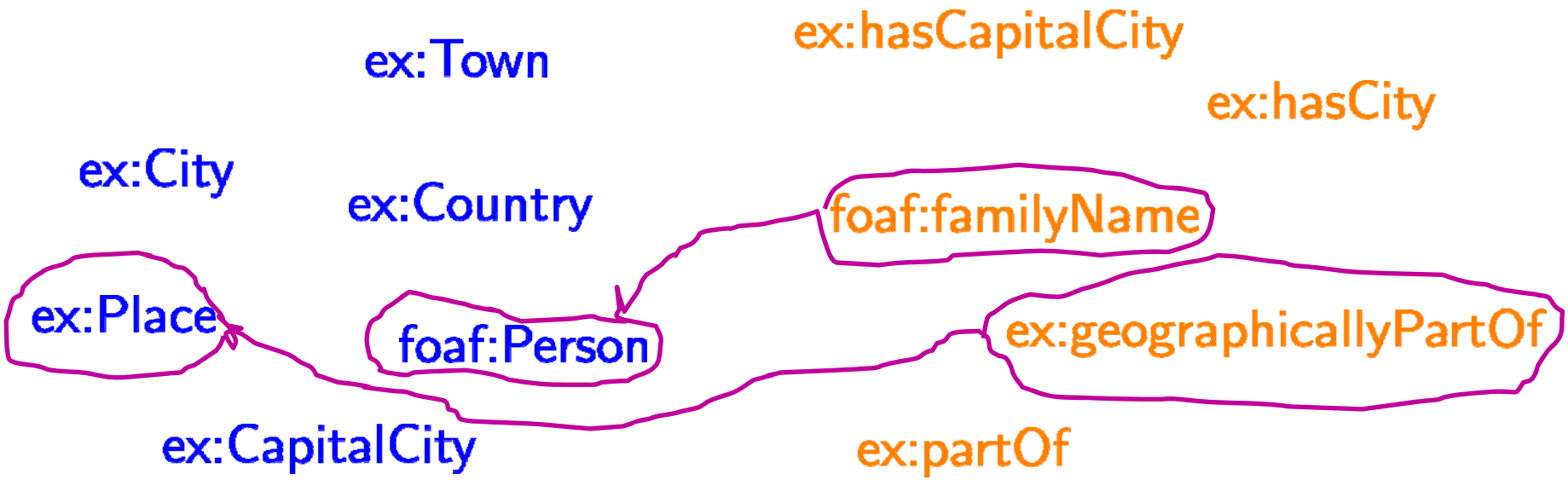


Domain of properties

- Property *p* has domain class *c*
  - If (x,*p*,y) then (x,rdf:type,*c*)

Example: if foaf:familyName *has domain* foaf:Person
and if (ex:Aidan,foaf:familyName,"Hogan")
then (ex:Aidan,rdf:type,foaf:Person)

Which properties would have which classes as domain?

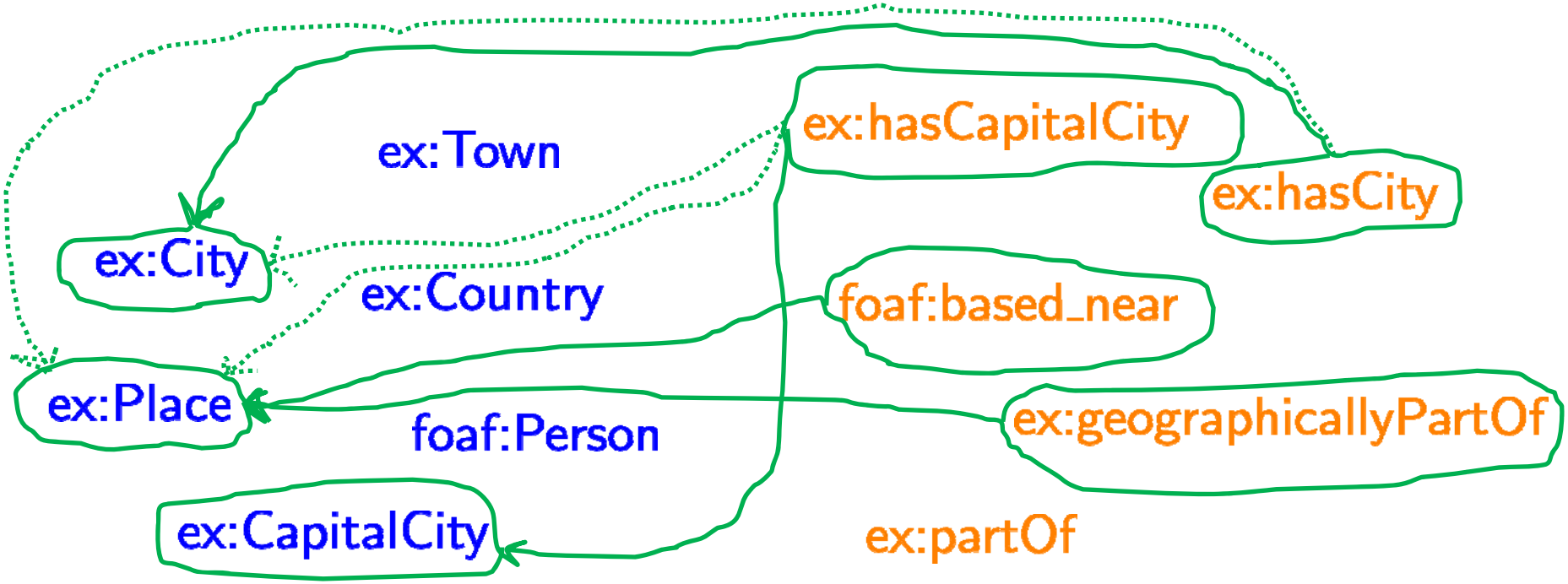


Range of properties

- Property *p* has range class *c*
  - If `(x,p,y)` then `(y,rdf:type,c)`

Example: if `ex:hasCity` *has range* `ex:City`
and if `(ex:Ireland,ex:hasCity,ex:Dublin)`
then `(ex:Dublin,rdf:type,ex:City)`

Which properties would have which classes as range?



Trade-off: More Specific, Less Reusable

- More specific, more conclusions!
- Less specific, more reusable!

- Example:
  - `ex:hasCapitalCity` has domain `ex:Country`

PRO: Know that anything that has a capital city is a country

CON: Cannot use this property for capital cities of states/counties/regions, etc.

Trade-off: More Specific, Less Reusable

- Another example:
  - `ex:Mayor` sub-class of `foaf:Person`

Bosco the dog

Mayor of Sunol, California

1981–1994

R.I.P.

Beware of “hidden” definitions!

FOAF Vocabulary Specification 0.99

Namespace Document 14 January 2014 - *Paddington Edition*

Property: foaf:img

image - An image that can be used to represent some thing (ie. those depictions which are particularly representative of something, eg. one's photo on a homepage).
Status: testing
Domain: having this property implies being a Person
Range: every value of this property is a Image

Do you see any potential problems here?

(ex:Dublin,foaf:img,ex:Dublin_night.jpg)

- Choose names of properties/classes carefully!

RDFS: RDF SCHEMA

RDFS: Describe “schema” in RDF

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

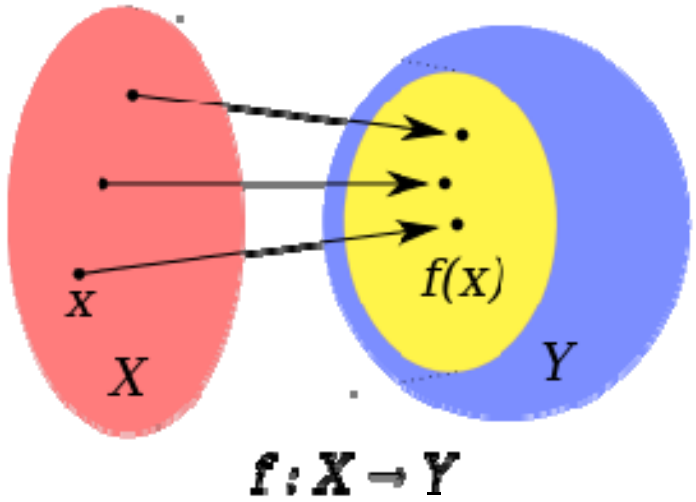
- Sub-class:
  - `ex:CapitalCity rdfs:subClassOf ex:City .`
- Sub-property:
  - `ex:hasCapitalCity rdfs:subPropertyOf ex:hasCity .`
- Domain:
  - `foaf:familyName rdfs:domain foaf:Person .`
- Range:
  - `ex:hasCapitalCity rdfs:range ex:CapitalCity .`
  - `foaf:familyName rdfs:range xsd:string .`

Note: Why called “domain” and “range”?

Any guesses why RDFS calls these “domain” and “range”

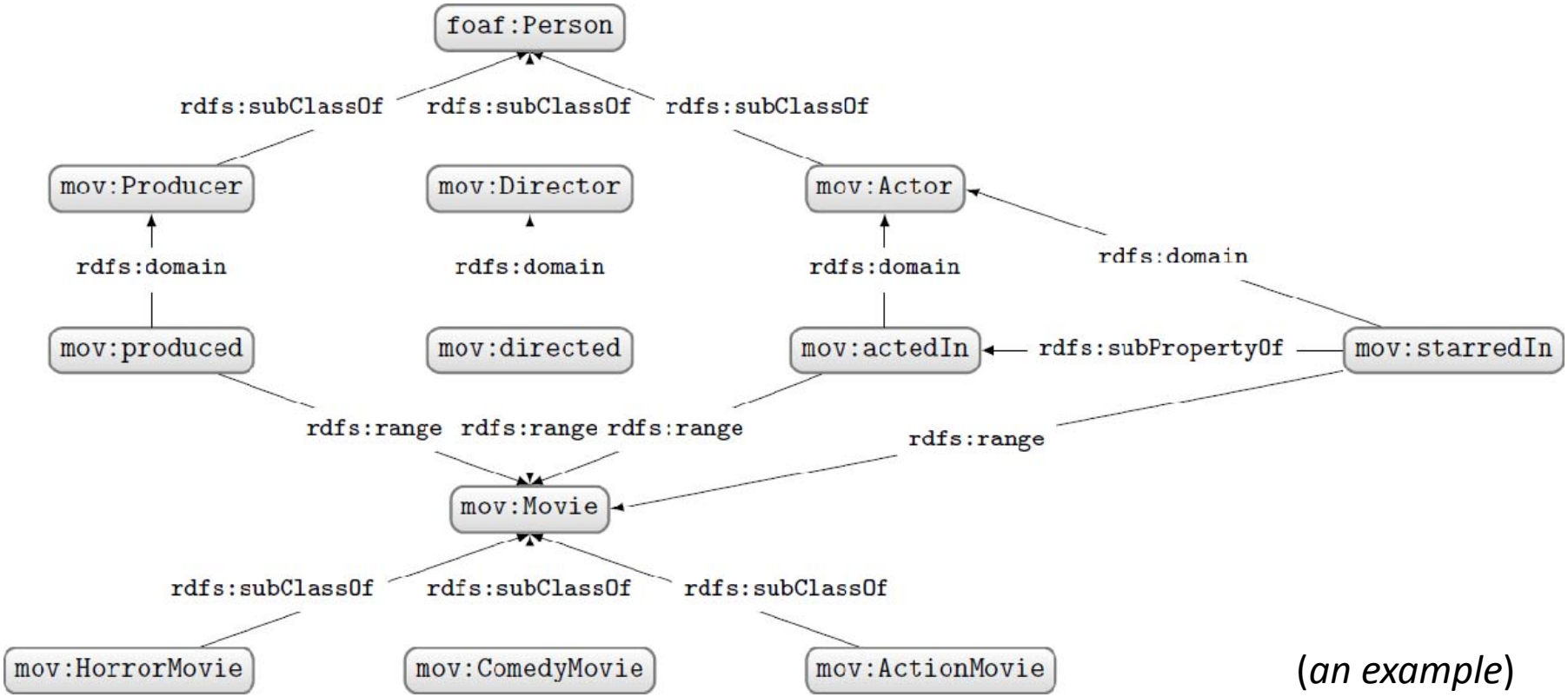
$f : X \rightarrow Y$

- X: **domain** of the function
- Y: co-domain of the function
- $\{f(x) \mid x \in X\}$: image or **range** of the function



So let's build an RDF Schema …

Let's model an RDF Schema for Movies, including different types of movies, some different types of people involved, and how they are related.



(*an example*)

But what, e.g., is the domain of … ?

But what, e.g., is the domain of … ?

- rdfs:Resource the class of everything!
  - Yes, even itself!
    - `(rdfs:Resource,rdf:type,rdfs:Resource)`

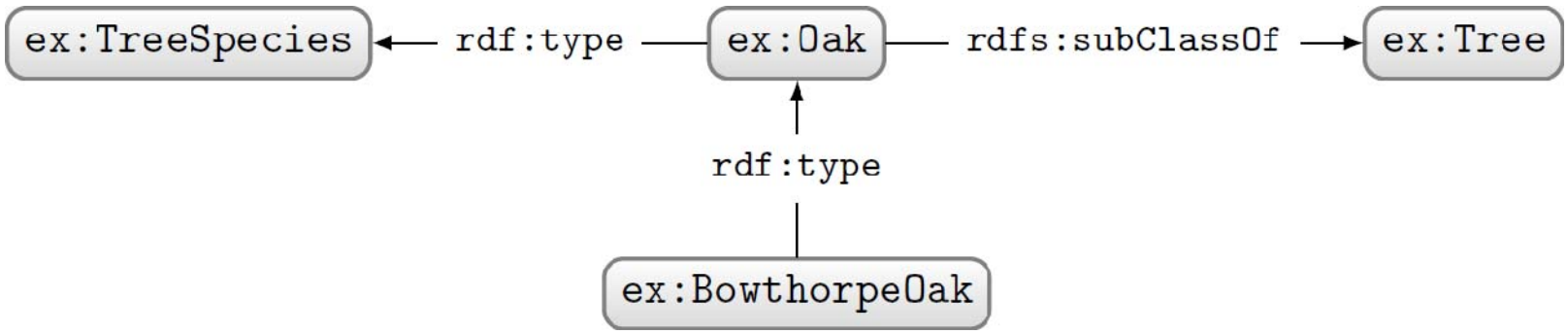
(Giving domain/range/sub-class rdfs:Resource says nothing new!)

Some meta-classes …

- rdf:Property: class of all properties
  - `(ex:hasCity,rdf:type,rdf:Property)`
- rdfs:Class: class of all classes
  - `(ex:City,rdf:type,rdfs:Class)`

Note: Class or instance?

Would you define ex:Oak (“roble”@es)
as a class or an instance?



No clear distinction between classes and instances!

REASONING WITH RDFS

What is “Reasoning”?

- Three types of reasoning:
  1. Inductive reasoning (learning)

     (learn fuzzy rule from premises and conclusions)

     “*The first three Sharknado movies were great, so the fourth will probably be great too.*”
  2. Deductive reasoning (logic)

     (make logical conclusion from given rule and premise)

     “*All movie directors are human. Anthony C. Ferrante is a movie director, therefore he/she/it must be human.*”
  3. Abductive reasoning (learning/logic)

     (guess the likely premise from a given rule and conclusion)

     “*All Sharknado movies involve sharks and tornados. Fred saw a movie with sharks and tornados. It was probably a Sharknado movie.*”

Reasoning in RDFS is deductive

- Three types of reasoning:
  1. Inductive reasoning (learning)

     (learn fuzzy rule from premises and conclusions)

     "The first three Sharknado movies were great, so the fourth will probably be great too."
  2. **Deductive reasoning (logic)**

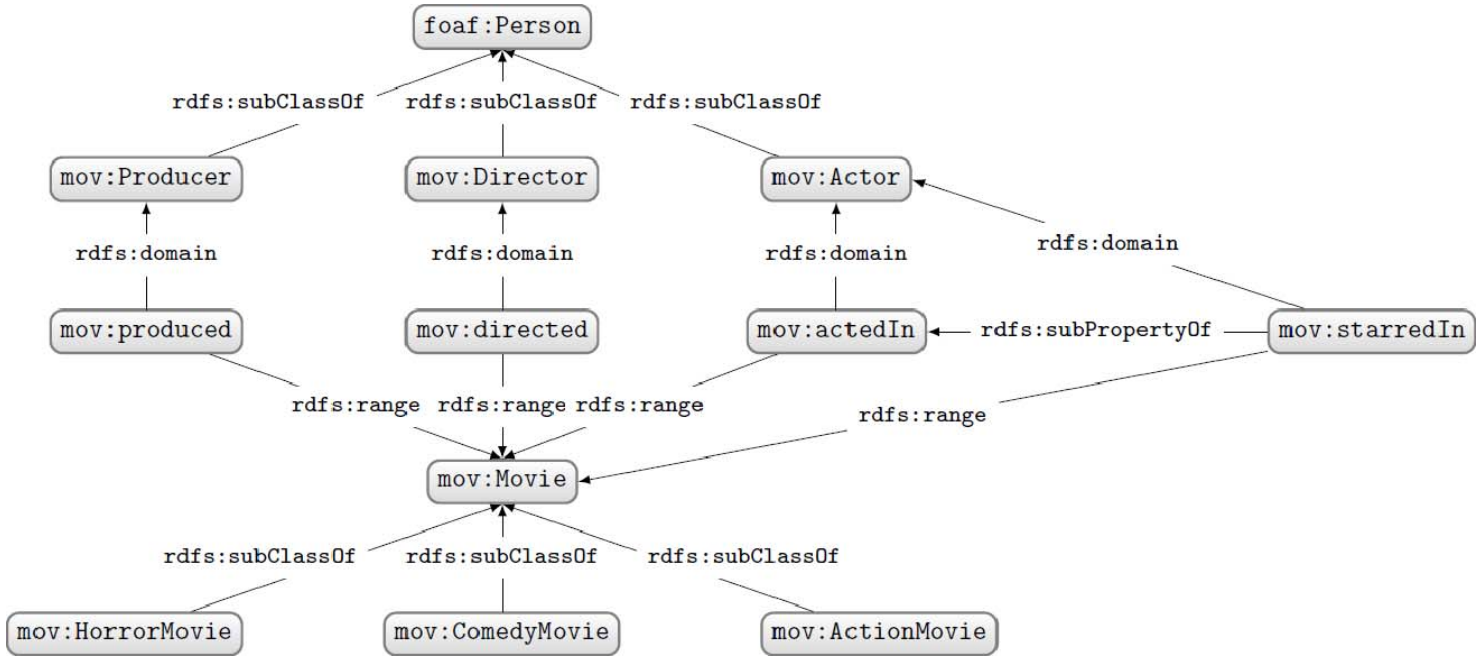
     (make logical conclusion from given rule and premise)

     "All movie directors are human. Anthony C. Ferrante is a movie director, therefore he/she/it must be human."
  3. Abductive reasoning (learning/logic)

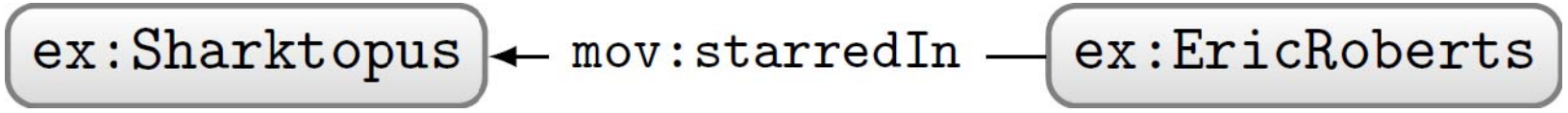
     (guess the likely premise from a given rule and conclusion)

     "All Sharknado movies involve sharks and tornados. Fred saw a movie with sharks and tornados. It was probably a Sharknado movie."

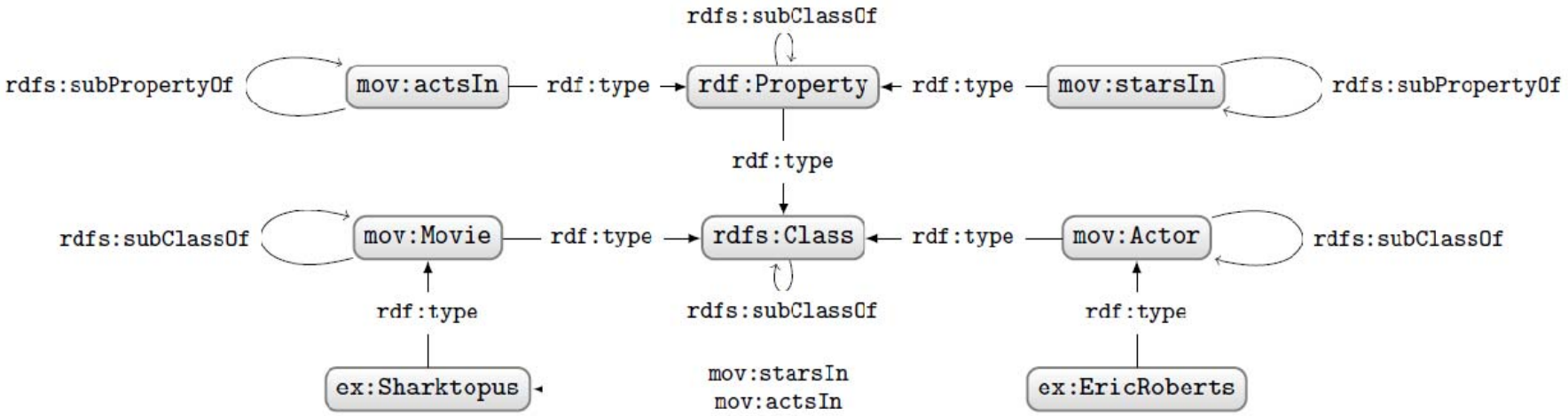
What conclusions can we deduce?



Given the above schema data, what can we deduce from:



Some of the conclusions …

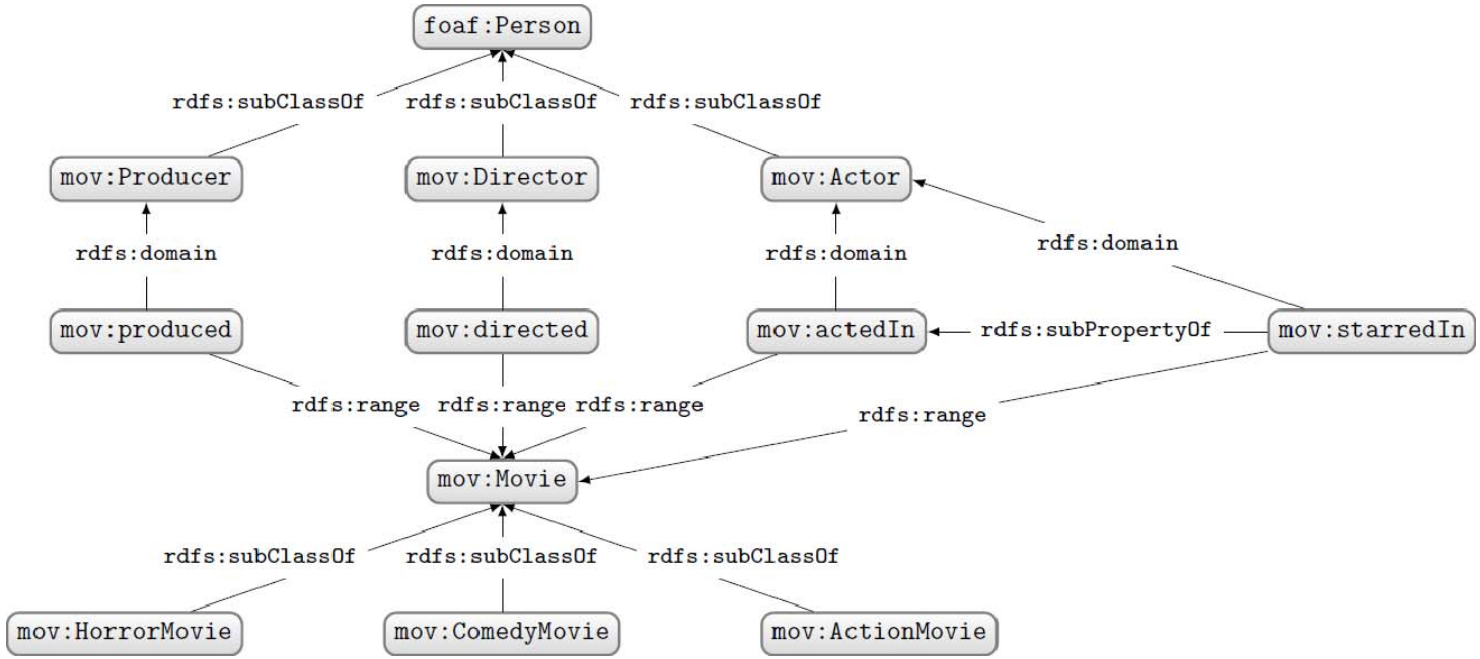


- Not shown (for sake of my/our sanity):
  - Everything of type rdfs:Resource
  - All classes sub-class of rdfs:Resource
  - RDF/RDFS properties of type rdf:Property
  - …
- A lot more data to answer queries with

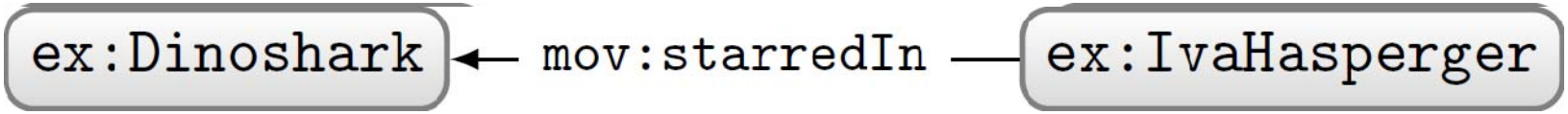
Just in case you're curious …

ex:Sharktopus ← mov:starredIn — ex:EricRoberts

Note: RDFS definitions apply to any movie!



Given the above schema data, what can we deduce from:



Apply RDFS reasoning using “rules”

ID	if G matches	then G RDFS$_D$-entails
rdfD1	?x ?p ?l . (?l a literal with datatype IRI dt(?l) $\in D$)	?x ?p _:b . _:b a dt(?l) .
rdfD2	?x ?p ?y .	?p a rdf:Property .
rdfs1	?u $\in D$	?u a rdfs:Datatype .
rdfs2	?p rdfs:domain ?c . ?x ?p ?y .	?x a ?c .
rdfs3	?p rdfs:range ?c . ?x ?p ?y .	?y a ?c .
rdfs4a	?x ?p ?y .	?x a rdfs:Resource .
rdfs4b	?x ?p ?y .	?y a rdfs:Resource .
rdfs5	?p rdfs:subPropertyOf ?q . ?x ?p ?y .	?x ?q ?y .
rdfs6	?p a rdf:Property .	?p rdfs:subPropertyOf ?p .
rdfs7	?p rdfs:subPropertyOf ?q . ?q rdfs:subPropertyOf ?r .	?p rdfs:subPropertyOf ?r .
rdfs8	?c a rdfs:Class .	?c rdfs:subClassOf rdfs:Resource .
rdfs9	?c rdfs:subClassOf ?d . ?x a ?c .	?x a ?d .
rdfs10	?c a rdfs:Class .	?c rdfs:subClassOf ?c .
rdfs11	?c rdfs:subClassOf ?d . ?d rdfs:subClassOf ?e .	?c rdfs:subClassOf ?e .
rdfs12	?p a rdfs:ContainerMembershipProperty .	?p rdfs:subPropertyOf rdfs:member .
rdfs13	?d a rdfs:Datatype .	?d rdfs:subClassOf rdf:Literal .

(Don’t worry about rdfD1, rdfs1, rdfs12, rdfs13)

Don’t forget “axiomatic triples”

```
rdf:type             rdfs:domain  rdfs:Resource ; rdfs:range  rdfs:Class     .
rdfs:domain          rdfs:domain  rdf:Property  ; rdfs:range  rdfs:Class     .
rdfs:range           rdfs:domain  rdf:Property  ; rdfs:range  rdfs:Class     .
rdfs:subPropertyOf   rdfs:domain  rdf:Property  ; rdfs:range  rdf:Property   .
rdfs:subClassOf      rdfs:domain  rdfs:Class     ; rdfs:range  rdfs:Class     .
rdf:subject          rdfs:domain  rdf:Statement ; rdfs:range  rdfs:Resource .
rdf:predicate        rdfs:domain  rdf:Statement ; rdfs:range  rdfs:Resource .
rdf:object           rdfs:domain  rdf:Statement ; rdfs:range  rdfs:Resource .
rdfs:member          rdfs:domain  rdfs:Resource ; rdfs:range  rdfs:Resource .
rdf:first            rdfs:domain  rdf:List      ; rdfs:range  rdfs:Resource .
rdf:rest             rdfs:domain  rdf:List      ; rdfs:range  rdfs:List     .
rdfs:seeAlso         rdfs:domain  rdfs:Resource ; rdfs:range  rdfs:Resource .
rdfs:isDefinedBy     rdfs:domain  rdfs:Resource ; rdfs:range  rdfs:Resource .
rdfs:comment         rdfs:domain  rdfs:Resource ; rdfs:range  rdfs:Literal  .
rdfs:label           rdfs:domain  rdfs:Resource ; rdfs:range  rdfs:Literal  .
rdf:value            rdfs:domain  rdfs:Resource ; rdfs:range  rdfs:Resource .
rdf:_n               rdfs:domain  rdfs:Resource ; rdfs:range  rdfs:Resource .

rdf:Alt                              rdfs:subClassOf  rdfs:Container .
rdf:Bag                              rdfs:subClassOf  rdfs:Container .
rdf:Seq                              rdfs:subClassOf  rdfs:Container .
rdfs:ContainerMembershipProperty     rdfs:subClassOf  rdf:Property   .
rdfs:Datatype                        rdfs:subClassOf  rdfs:Class      .

rdfs:isDefinedBy  rdfs:subPropertyOf  rdfs:seeAlso .

rdf:_n  rdf:type  rdfs:ContainerMembershipProperty .
```

Reasoning in RDFS over RDF graph *G*

1. Add axiomatic triples to *G*
2. Apply rules exhaustively, adding conclusions to *G*, until nothing new found

Will this ever finish? Or will it run forever?

RECAP

(1) Data, **(2) Rules/Ontologies**, (3) Query

INPUT: "(x,partOf,y)"

DATA:

`http://ex.org/Ireland`

Ireland 

(Ireland,partOf,Europe)
(Ireland,a,Country)
(Ireland,capital,Dublin)

`http://ex.org/Dublin`

Dublin 

(Dublin,population,1000000)

RULES: $(a, \text{capital}, b) \rightarrow (b, \text{partOf}, a)$
$(c, \text{partOf}, d), (d, \text{partOf}, e) \rightarrow (c, \text{partOf}, e)$

OUTPUT: $\{(x \mapsto \text{Ireland}, y \mapsto \text{Europe}), (x \mapsto \text{Dublin}, y \mapsto \text{Ireland})$
$(x \mapsto \text{Dublin}, y \mapsto \text{Europe})\}$

Don’t write rules: write triples

- RDFS: RDF Schema
  - Allows for defining classes and properties
  - Written down in triples
  - Can be used for reasoning with rules

RDFS: RDF Schema

- RDFS has four main features:
  - sub-class: an instance of a class *c1* is an instance of its sub-class *c2*
  - sub-property: if two things are related by *p1*, they are also related by its sub-property *p2*
  - domain: the subject of a relation with property *p* is the type of its domain *c*
  - range: the object of a relation with property *p* is the type of its range *c*
- A few other useful classes:
  - rdf:Property: the class of all properties
  - rdfs:Class: the class of all classes
  - rdfs:Resource: the class of everything!

RDFS: A Web Standard

http://www.w3.org/TR/rdf-schema/

W3C Recommendation

RDF Schema 1.1

W3C Recommendation 25 February 2014

This version:
http://www.w3.org/TR/2014/REC-rdf-schema-20140225/
Latest published version:
http://www.w3.org/TR/rdf-schema/
Previous version:
http://www.w3.org/TR/2014/PER-rdf-schema-20140109/
Editors:
Dan Brickley, Google
R.V. Guha, Google
Previous Editors:
Brian McBride

Please check the **errata** for any errors or issues reported since publication.

This document is also available in this non-normative format: diff w.r.t. 2004 Recommendation

Questions?