Foundations of Semantic Knowledge Graphs

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Logical Inferencing using RDF Schema

Knowledge Representation Formulas: What we can express using formal semantics...

Conditions on class membership

- all mammals are warm-blooded
- if you don't eat meat, you are a vegetarian

Relation between classes

- all cities are populated cities
- every class is equivalent to itself

Assertions on class membership

- Darmstadt is a city

Characteristics on properties

- hasCapital only relates to countries or cities
- partOf is a transitive property

Assertions on property relations

- hasCapital(Berlin, Germany)

Assertions on equality

- morning star = evening star = venus

Basic Inferencing: Class membership and hierarchy entailments

- Specify that something (denoted by an IRI/URI) is a **class** (or a property)

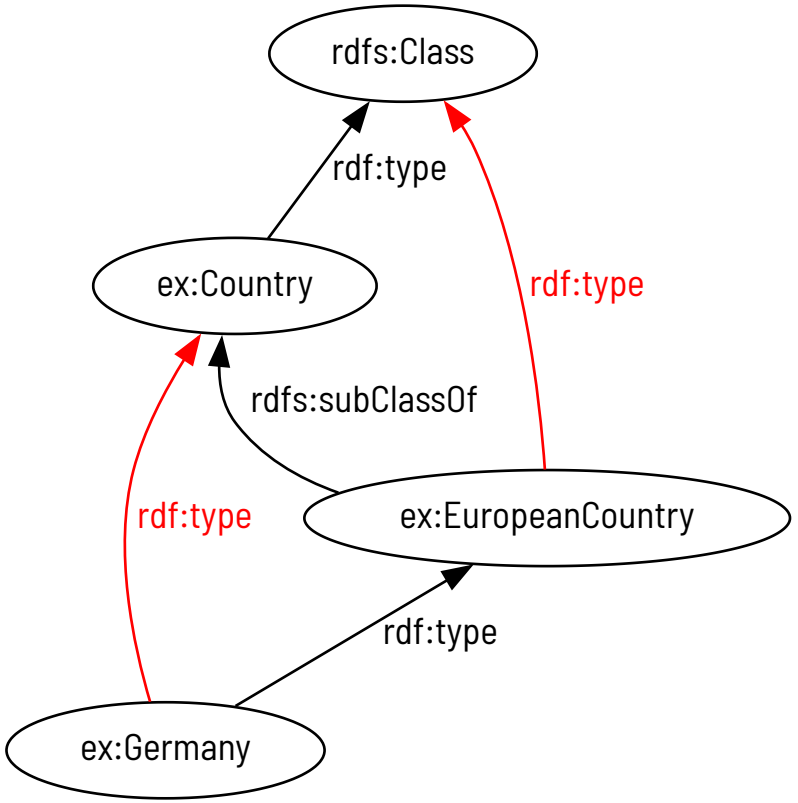
```
ex:Country          rdf:type            rdfs:Class .
```

- Specify that something is a **member** of a **class**

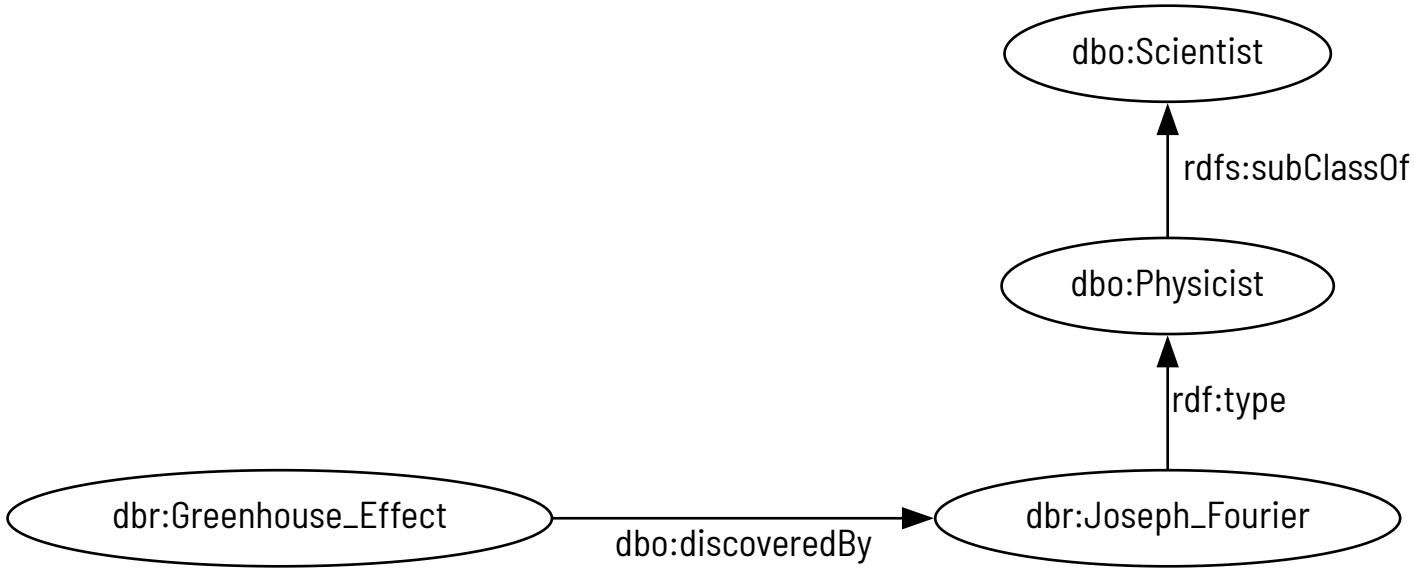
```
ex:Germany          rdf:type            ex:EuropeanCountry .
```

- Specify that something is a **subclass** of another class

```
ex:EuropeanCountry  rdfs:subClassOf     ex:Country .
```



Basic Inferencing: Another Example

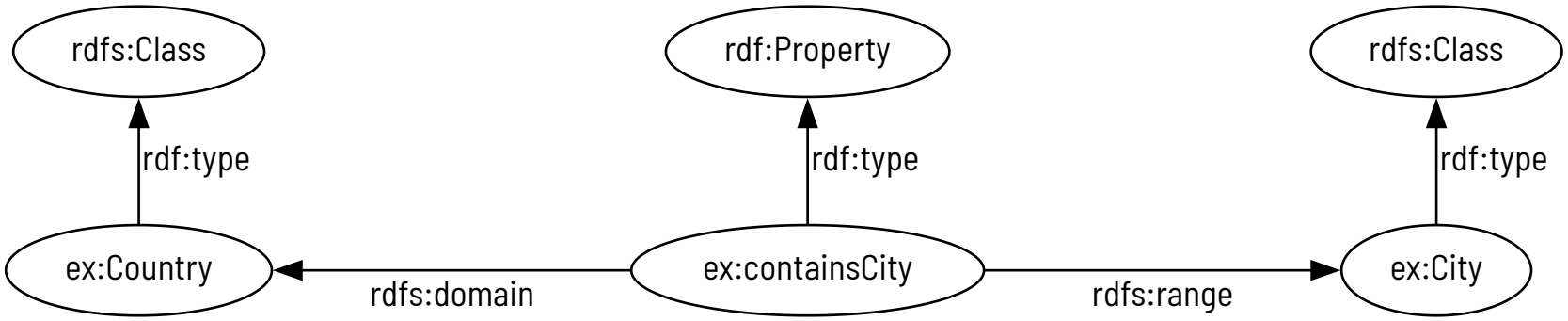


Deduction of new facts from class hierarchy

$$\forall i, c_1, c_2 : T(i, \text{rdf:type}, c_1) \wedge T(c_1, \text{rdfs:subClassOf}, c_2) \rightarrow T(i, \text{rdf:type}, c2)$$

$\Rightarrow$ *"The greenhouse effect was discovered by a scientist."*

Basic Inferencing: Domain and range restrictions

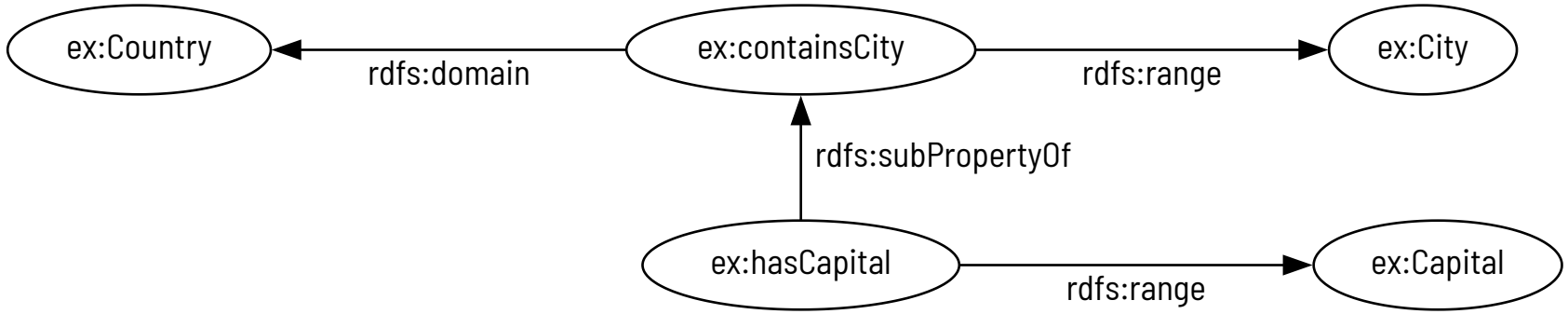


- Specify that some property **always** relates members of **specific classes**.

```
ex:Germany      ex:containsCity     ex:Berlin .     <!-- from this statement -->
-----------------------------------------------
ex:Germany      rdf:type            ex:Country .    <!-- inferred statements -->
ex:Berlin       rdf:type            ex:City .                   ...
```

- This entailment rule also propagates down to **subproperties** (see next slide)

Basic Inferencing: Propagation of domain and range restrictions



- Domain and range restrictions also propagate along **property hierarchies**.

```
ex:Germany      ex:hasCapital       ex:Berlin .     <!-- from this statement -->
-------------------------------------------------
ex:Berlin       rdf:type            ex:Capital .    <!-- inferred statements -->
ex:Berlin       rdf:type            ex:City .                   ...
ex:Germany      ex:containsCity     ex:Berlin .
ex:Germany      rdf:type            ex:Country .
```

RDF Schema: Some useful information

- Specify a human readable label for terms and resources

```
ex:Country      rdfs:label          "Land"@de .
```

- Add comments to a resource

```
ex:Darmstadt    rdfs:comment        "Darmstadt is a city located in the south of the federal state Hessen" .
```

- Refer to another resource (central concept of Linked Open Data)

```
ex:Darmstadt    rdfs:seeAlso        dbr:Darmstadt .
```

RDF Schema: Observations 🔭

- **Properties** are first-class citizen
  ...not part of classes as in object oriented programming (OOP/UML)
  ...domain and range restrictions are tricky and should be avoided
- No strict distinction between **schema** and **data level**
- RDF Schema entailment rules do not include **negation**
- No notion of **equality**

RDF Schema: Summary

- Without **formal semantics**, the Web of Data is **meaningless**
- Distinction between **classes**, **properties**, and **instances** (schema vs. data)
- RDF Schema employs a number of **reserved symbols** (ie language terms) for defining individual vocabularies
- **Entailment rules** are expressed using reserved symbols
  ⇝ are computed based on the semantics of reserved symbols
- **Inferencing** denotes the application of entailment rules to formulas to produce **new facts**
- RDF Schema is **not** very **expressive**