IN3060/4060 – Semantic Technologies – Spring 2021

Lecture 6: Introduction to Reasoning with RDF

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Mandatory exercises

- Oblig 4 published after this lecture.

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- Hand-in by Friday in two weeks (05/03/2021).

Today's Plan

1. Inference rules
2. RDFS Basics
3. Backwards and forwards reasoning
4. RDFS reasoning in Jena

Outline

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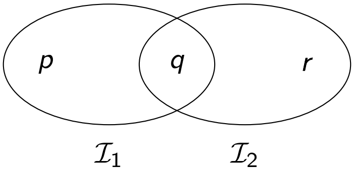

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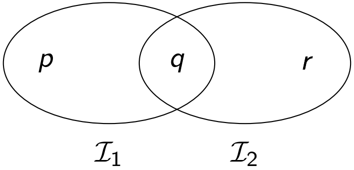

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Syntactic reasoning easier to understand and use than model semantics

- we will show that first.

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Where $\models$ is the entailment relation, $\vdash$ is the inference relation. We write $\Gamma \vdash P$ if we can deduce P from the assumptions Γ.

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Inference rules in propositional logic

(Part of) Natural deduction calclulus for propositional logic:

$$\frac{A \qquad (A \rightarrow B)}{B} \rightarrow E$$

$$\frac{(A \wedge B)}{A} \wedge E_l \qquad \frac{(A \wedge B)}{B} \wedge E_r \qquad \frac{A \qquad B}{(A \wedge B)} \wedge I$$

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- "If $P_1, \ldots, P_n$ are all in the store, *add* P to the store."

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- and (for our purposes) a subset of OWL.

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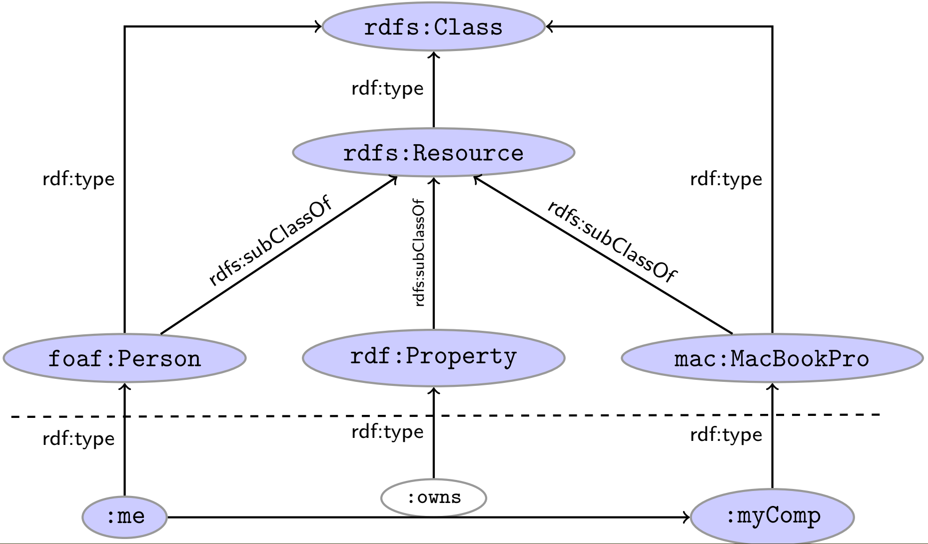
  - `rdfs:subPropertyOf`: Property inclusion.

Example


rdfs:Class
rdf:type
rdfs:Resource
rdf:type
rdfs:subClassOf
rdfs:subClassOf
rdfs:subClassOf
rdf:type
foaf:Person
rdf:Property
mac:MacBookPro
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RDFS	Set Theory
A `rdf:type rdfs:Class`	A is a set of resources
x `rdf:type` A	$x \in A$
A `rdfs:subClassOf` B	$A \subseteq B$

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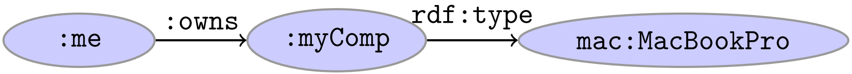
- $\dfrac{\texttt{A R B .}}{\texttt{A R \_:x .}}\ \text{se1} \qquad \dfrac{\texttt{A R B .}}{\texttt{\_:x R B .}}\ \text{se2}$
- Where `_:x` is a blank node identifier, that either
  - has not been used before in the graph, or
  - has been used, but for the same URI/Literal/Blank node.
  - `_:x` represents `B` in se1 and `A` in se2.

Simple Entailment Example

- Let's create the RDF-graph with the two triples:
  1. `:me :owns :myComp .`
  2. `:myComp rdf:type mac:MacBookPro .`



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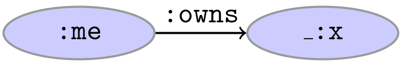

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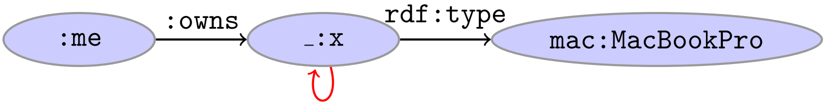

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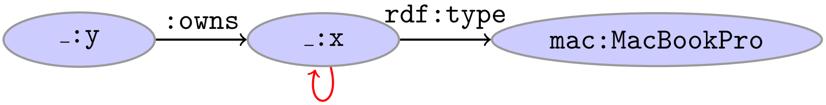

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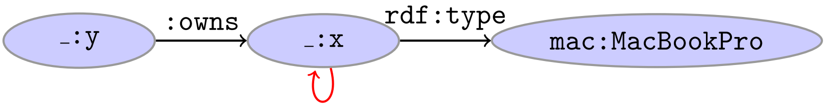

We can *not* infer `_:x :owns _:x` because `_:x` was used for another URI.

RDFS reasoning

RDFS supports three principal kinds of *reasoning pattern*:

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   - "All *father*s of people are *male*s. James is the *father* of Karl, therefore…"

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(... and also for the other classes)

A typical taxonomy

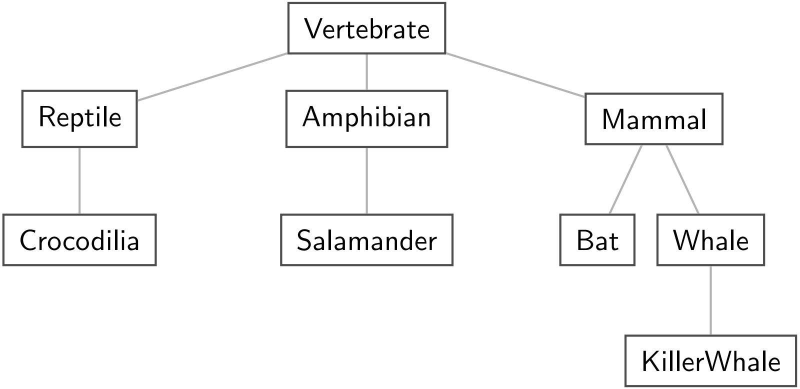

Figure: A typical taxonomy

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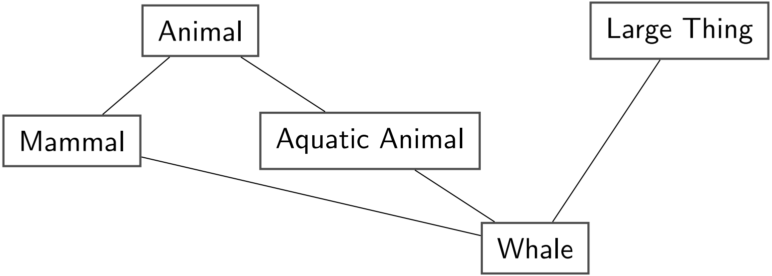

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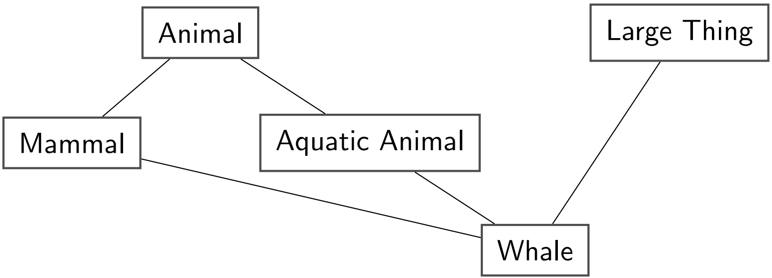

- This is usually not called a *taxonomy*, but it's no problem for RDFS.

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:author rdfs:subPropertyOf dcterms:creator .
:writer rdfs:subPropertyOf dcterms:creator .
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- Legacy applications that use e.g. `author` can operate unmodified.

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Organising the properties

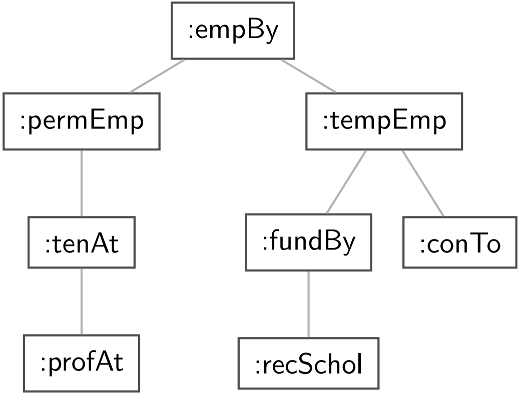

Figure: A hierarchy of employment relations

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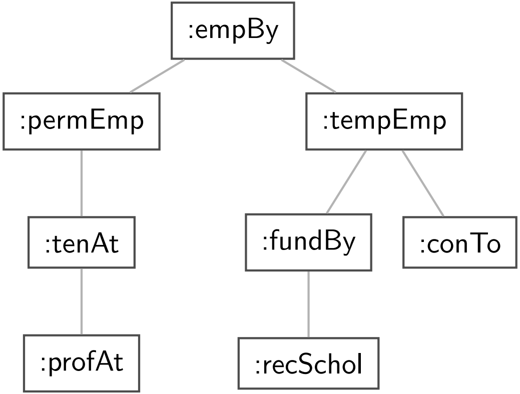

Figure: A hierarchy of employment relations

- Note: doesn't have to be tree-shaped.

Querying the inferred model

Formalising the tree:

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Given a data set such as:

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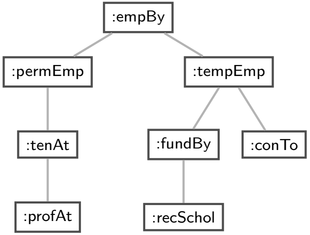

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We may now query on different levels of abstraction :

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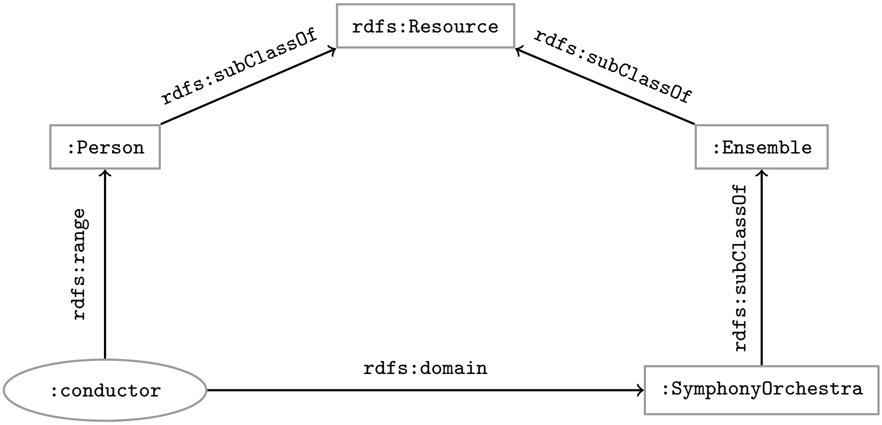

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and may be used as a type in SPARQL (reasoner presupposed):

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RDFS axiomatic triples (excerpt)

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  - `:Person rdfs:type rdfs:Resource`
  - `rdfs:Class rdfs:type rdfs:Class`
  - ...

Using the Axiomatic Triples

- From the statement
  `:conductor rdfs:range :Person`
- We can derive:
  - `:conductor rdf:type rdf:Property`
  - `:Person rdf:type rdfs:Class`
  - `:conductor rdf:type rdfs:Resource`
  - `rdf:Property rdf:type rdfs:Class`
  - `:Person rdfs:type rdfs:Resource`
  - `rdfs:Class rdfs:type rdfs:Class`
  - ...
- In OWL, there are some simplification which make this superfluous.

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Outline

Forward chaining vs. backward chaining

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Forward chaining:

- reasoning from premises to conclusions of rules

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- reasoning is on-demand

Forward chaining inference

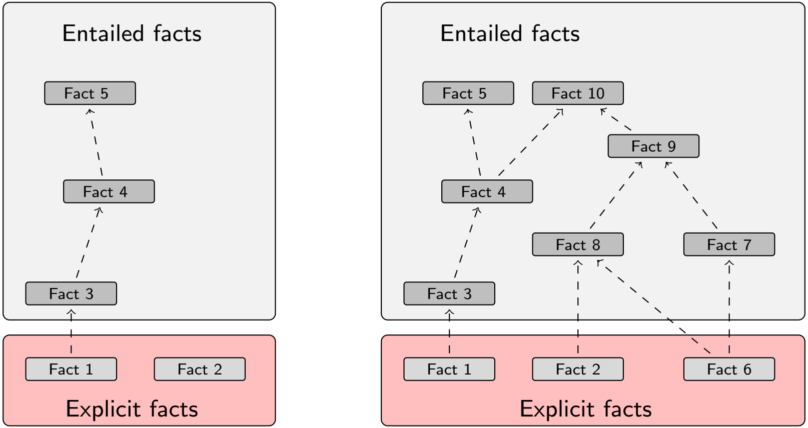

Figure: When a fact is added, all entailments are computed and stored.

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Precomputing and storing answers is suitable for data which is:

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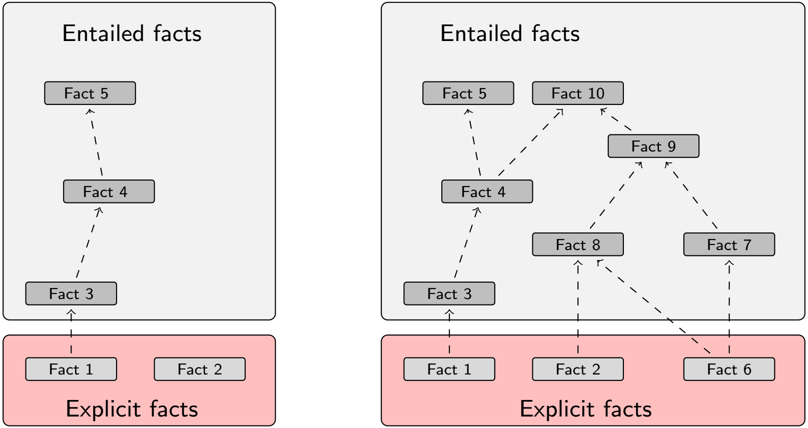
- forward chaining optimizes retrieval
- no additional inference is necessary at query time

Forward chaining and truth-maintenance



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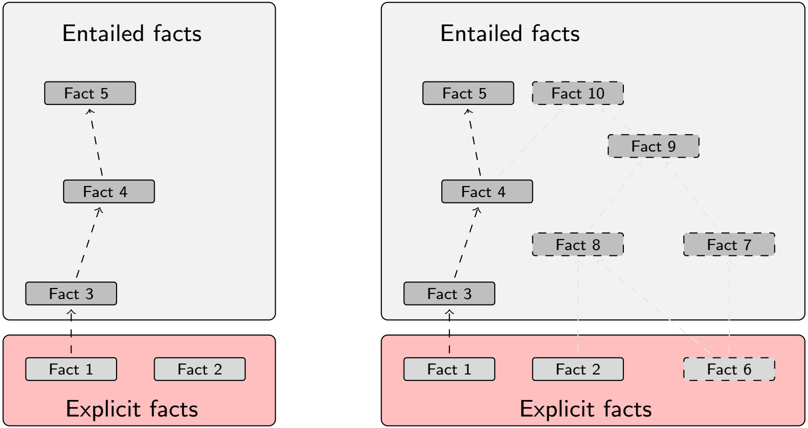

Figure: When a fact is removed, everything that comes with it must go too.

Drawbacks of forward chaining

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- problematic for distributed and/or dynamic systems
  - rules could apply to premisses on different disks, etc.

Backward chaining inference

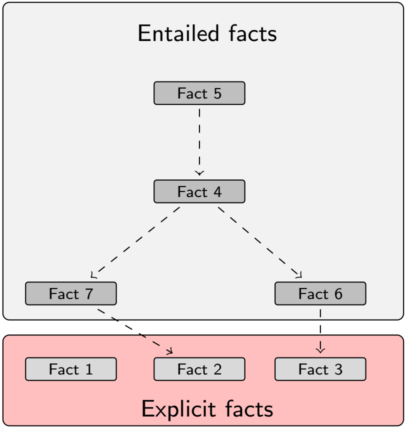

Figure: Backward chaining uses rules to expand queries.

Backward chaining: Example

RDFS/RDF knowledge base:

```
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Model sche = FileManager.get().loadModel(aURI);
Model dat = FileManager.get().loadModel(bURI);
InfModel inferredModel = ModelFactory.createRDFSModel(sche, dat);
```

method `createRDFSModel()` returns an `InfModel`

- An `InfModel` has a basic inference API, such as;
  - `getDeductionsModel()` which returns the inferred triples,
  - `getRawModel()` which returns the base triples,
  - `getReasoner()` which returns the RDFS reasoner,

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  - `getReasoner()` which returns the RDFS reasoner,
  - `getDerivation(stmt)` which returns a trace of the derivation

Example II: Using static methods in the registry

using ModelFactory.createInfModel

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Model sche = FileManager.get().loadModel(aURI);
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Reasoner reas = ReasonerRegistry.getOWLReasoner();
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- similar for built-in and external reasoners alike

Conclusion

- We have seen that by modelling knowledge using the URIs in the RDF and RDFS vocabularies (e.g. `rdf:type`, `rdfs:subClassOf`, `rdfs:range`), the computer can derive *new* triples, that follows from our original triples.

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- Example of large ontology, BabelNet: `http://www.babelnet.org/`
- OWL will also allow us to express more complex statements and use more complex types of reasoning.

That's it for today!

Remember the oblig!