INF3580 – Semantic Technologies – Spring 2011

Lecture 7: Reasoners in Jena

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Today's Plan

Outline

What is inference?

In a Semantic Web context, inference always means,

- adding triples,

More specifically it means,

- adding new triples to an RDF graph,
- on the basis of the triples already in it.
- 'adding' should be understood in a logical sense, indeed;
  - new/entailed triples need not be materialized or persisted
  - indeed they may be ephemeral and transitory

cont.

A rule of the form

$$\frac{P_1, \ldots, P_n}{P}$$

may be read as an instruction;

- "If $P_1, \ldots, P_n$ are all in the graph, add P to the graph"
- as an *instruction* this may in turn be understood *procedurally* ...
  - in a forward sense, or
  - in a backward sense

RDFS reasoning

RDFS supports three principal kinds of reasoning pattern:

I. Type propagation:
   - "The 2CV is a car, and a car is a motorised vehicle, so..."

II. Property inheritance:
   - "Martin lectures at Ifi, and anyone who does so is employed by Ifi, so..."

III. Domain and range reasoning:
   - "Everything someone has written is a document. Martin has written a PhD thesis, therefore..."
   - "All fathers of people are males. Martin is the father of Karl, therefore..."

Sample RDFS rules

Rules for property transfer

- Transitivity:

$$\frac{\texttt{p rdfs:subPropertyOf q .} \quad \texttt{q rdfs:subPropertyOf r .}}{\texttt{p rdfs:subPropertyOf r .}} \text{rdfs5}$$

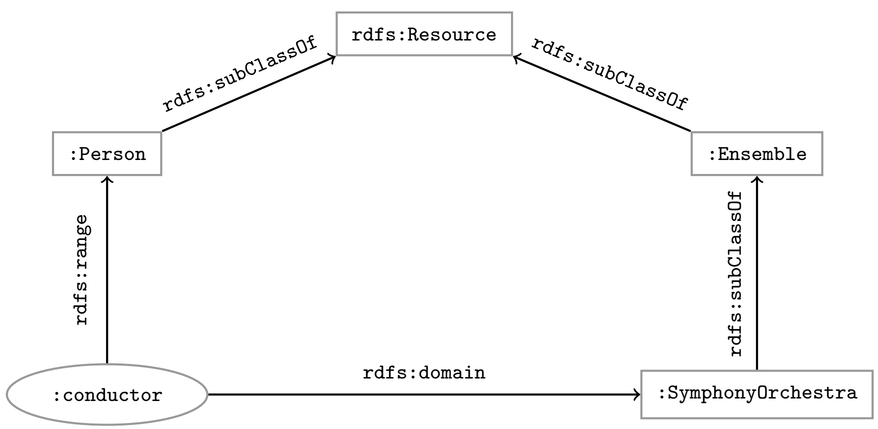
- Reflexivity:

$$\frac{\texttt{p rdf:type rdf:Property .}}{\texttt{p rdfs:subPropertyOf p .}} \text{rdfs6}$$

- Property transfer:

$$\frac{\texttt{p rdfs:subPropertyOf q .} \quad \texttt{u p v .}}{\texttt{u q v .}} \text{rdfs7}$$

Example: Conductors and ensembles



Example contd.

This ontolology includes

```
:SymphonyOrchestra rdfs:subClassOf :Ensemble .
:conductor rdfs:domain :SymphonyOrchestra .
:conductor rdfs:range :Person .
```

the data includes

```
:OsloPhilharmonic :conductor :Petrenko .
```

but interestingly not

```
:OsloPhilharmonic rdf:type :SymphonyOrchestra .
```

the entailments include

```
:OsloPhilharmonic rdf:type :SymphonyOrchestra .
:OsloPhilharmonic rdf:type :Ensemble .
:Petrenko rdf:type :Person .
```


Outline

Forward chaining vs. backward chaining

Forward chaining:

- reasoning from premises to conclusion of rules
- adds facts corresponding to the conclusions of rules
- entailed facts are stored and reused

Backward chaining:

- reasoning from conclusions to premises
- ' ... what needs to be true for this conclusion to hold?'
- entailment is on-demand

Forward chaining inference

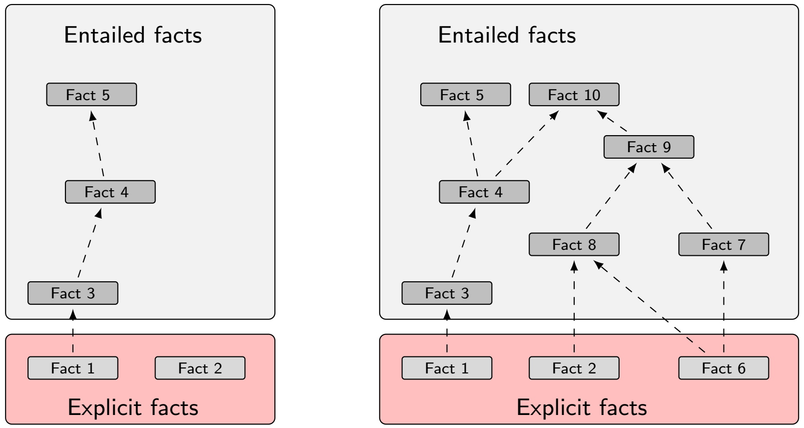


Figure: When a fact is added, all entailments are computed and stored.

Benefits of forward chaining

Precomputing and storing answers is suitable for:

- frequently accessed data
- which it is expensive to compute,
- which is relatively static,
- and which is small enough to efficiently store

Benefits:

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

Forward chaining and truth-maintenance

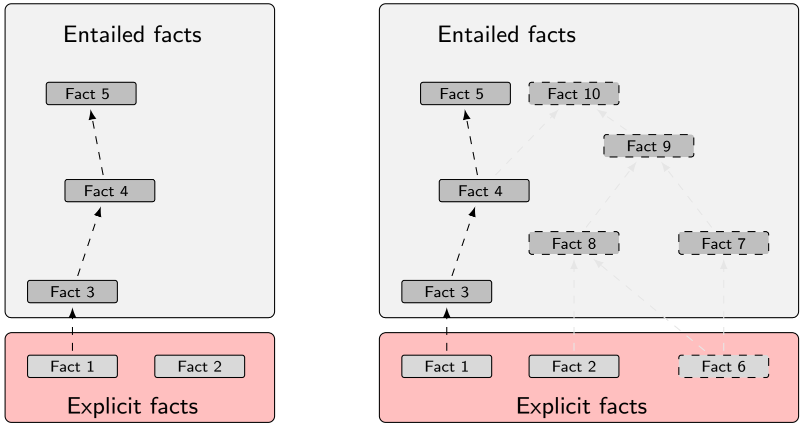


Figure: When a fact is removed, everything that comes with it must go too.

Drawbacks of forward chaining

Drawbacks:

- increases storage size
- increases the overhead of insertion
- removal is highly problematic
- truth maintenance usually not implemented in RDF stores
- not suitable for distributed and/or dynamic systems
- (... as there is usually nowhere to persist the data)

Backward chaining inference

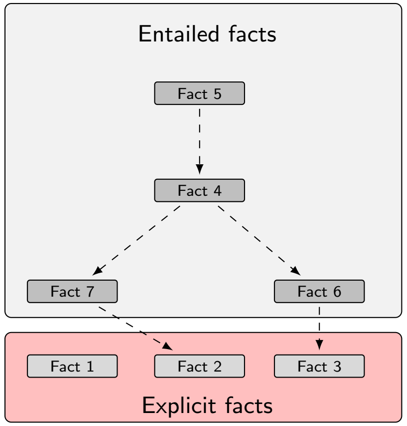


Figure: Backward chaining uses rules to expand queries.

Drawbacks and benefits of backward chaining

Computing answers on demand is suitable where:

- there is little need for reuse of computed answers
- answers can be efficiently computed at runtime
- answers come from multiple dynamic sources

Benefits:

- only the relevant inferences are drawn
- truth maintenance is automatic
- no persistent storage space needed

Drawbacks:

- trades insertion overhead for access overhead
- without caching, answers must be recomputed every time

Outline

Quick facts

In Jena there is

- a zillion ways to configure and plug-in a reasoner
- some seem rather haphazard

Imposing order at the cost of precision we may say that ...

- reasoners fall into one of two categories
  - built-in- and
  - external reasoners
- ... and are combined with two kinds of model
  - models of type `InfModel`, and
  - models of type `OntModel`

Moreover ...

- Different reasoners implement different logics, e.g
  - Transitive reasoning,
  - RDFS,
  - OWL
- There is a `ReasonerFactory` class for each type of reasoner,
  - which is used to create `Reasoner` objects
  - they are all stored in a global `ReasonerRegistry` class
  - which can be manipulated explicitly or implicitly

The road most often travelled ...

Applications normally access the inference machinery by

- using the `ModelFactory`
- to associate a dataset with some reasoner
- producing a new model with reasoning capabilities

The `ModelFactory` may

- create an `InfModel` via convenience methods on the `Registry`, or
- create an `OntModel` and pass it an `OntModelSpec`

.... Confusing? Stay tuned ....

Simplified overview

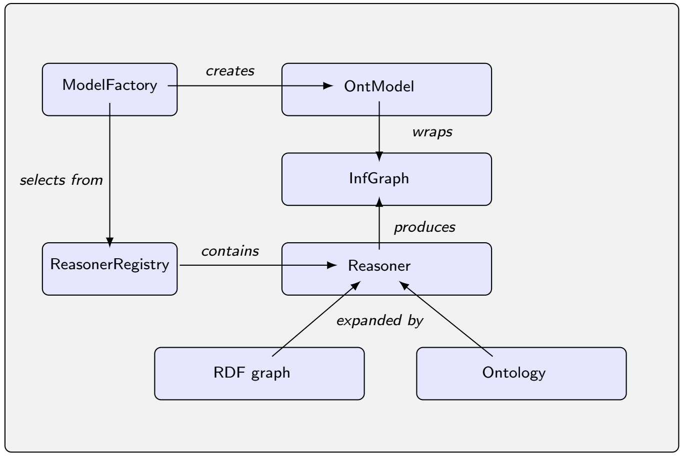


Figure: The structure of the reasoning system

Built-in reasoners

Transitive reasoners:

- provides support for simple taxonomy traversal
- implements only the reflexivity and transitivity of
  - `rdfs:subPropertyOf`, and
  - `rdfs:subClassOf`.

RDFS reasoners:

- supports (most of) the axioms and inference rules specific to RDFS.

OWL, OWL mini/micro reasoners:

- implements different subsets of the OWL specification

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Obtaining a built-in reasoner

Three main ways of obtaining a built-in reasoner:

1. call a convenience method on the `ModelFactory`
   - which calls a `ReasonerFactory` in the `ReasonerRegistry`, and
   - returns an `InfModel` all in one go
2. call a static method in the `ReasonerRegistry`,
   - the static method returns a reasoner object
   - pass it to `ModelFactory.createInfModel()`
   - along with a model and a dataset
3. use a reasoner factory directly
   - covered in connection with external reasoners later

Example I: Using a convenience method

A simple RDFS model

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

Example II: Using static methods in the registry

using `ModelFactory.createInfModel`

```
Model sche = FileManager.get().LoadModel(aURI);
Model dat = FileManager.get().LoadModel(bURI);

Reasoner reas = ReasonerRegistry.getOWLReasoner();
InfModel inf = ModelFactory.createInfModel(reas, sche, dat);
```

Virtues of this approach:

- we retain a reference to the reasoner,
- that can be used to configure it
  - e.g. to do backwards or forwards chaining
  - ... mind you, not all reasoners can do both
- similar for built-in and external reasoners alike

Outline

An *OntModel* is ontology-aware

An `InfModel` provides

- basic functionality associated with the reasoner, and
- basic functionality to sort entailed from explicit statements
- ... but no fine-grained control over an ontology

An `OntModel` provides

- a richer view of a knowledge base
- in terms of ontological concepts
- mirrored by methods such as
  - `createClass()`
  - `createDatatypeProperty()`
  - `getIntersectionClass()`

contd.

An *OntModel* does not by itself compute entailments

- it is merely a wrapper
- that provides a convenient API
- given that your data is described by an ontology

However,

- an `OntModel` can be constructed according to a specification object
- that, among other things, tells Jena which reasoner to use

More generally, an `OntModelSpec` encapsulates

- the storage scheme,
- language profile,
- and the reasoner associated with a particular `OntModel`

Some predefined specification objects

The class `OntModelSpec` contains static references to prebuilt instances:

`OWL_DL_MEM_RDFS_INF`: In-memory OWL DL model that uses the RDFS inference engine.

`OWL_LITE_MEM`: In-memory OWL Lite model. No reasoning.

`OWL_MEM_MICRO_RULE_INF`: In-memory OWL model uses the OWLMicro inference engine.

`OWL_DL_MEM`: In-Memory OWL DL model. No reasoning.

Example: Configuring an `OntModel`

An `OntModel` is created by calling a method in `ModelFactory`

Specifying an `OntModel`

```
OntModelSpec spec = new OntModelSpec(OntModelSpec.OWL_DL_MEM);
OntModel model = ModelFactory.createOntologyModel(spec, model);
```

Jena currently lags behind

- no spec for OWL 2
- ... or any of its profiles
- does not mean that we cannot use OWL 2 ontologies with Jena
- but we do not have support in the API for all language constructs
- some reasoners supply their own such API, e.g. Pellet

Outline

Plugging in third-party reasoners

Jena's reasoning-system architecture makes it easy ...

- for third party vendors to write reasoners
- that can be plugged in to Jena architecture

External reasoners usually

- check in a `ReasonerFactory` in the `ReasonerRegistry`, and
- supply a `OntModelSpec` to be handed to the `ModelFactory`

Some better known ones

There are many, many reasoners to choose from, e.g.

- FaCT++
- Cerebra Engine
- CEL
- HermiT
- Pellet

Reasoning algorithms vary with purpose, scope, philsophy and age (!);

- tableu reasoners (FaCt++, Pellet, Cerebra)
- rule-based reasoners (CEL)
- hyper-tableu (HermiT)
- only rule reasoners have a notion of forwards vs. backwards

Using an external reasoner

- retrieve an instance of the reasoner:

```
Reasoner r;
r = PelletReasonerFactory.theInstance().create();
```

- associate the reasoner with an `InfModel`, an ontology and a dataset:

```
InfModel inf;
inf = ModelFactory.createInfModel(r, ontology, dataset);
```

- wrap it in an `OntModel` for a richer API:

```
OntModel m;
m = ModelFactory.createOntologyModel(
    PelletReasonerFactory.THE_SPEC, inf);
```

Outline

Integrating information from DBpedia

Quick facts about the DBpedia project:

- aims to extract structured content form Wikipedia
- it is a community effort, so ..
- the data is not always uniform and consistent
- distinct properties for 'intuitively similar' objects not uncommon, e.g.;
  - `dbprop:doctoralStudents`
  - `dbpedia:doctoralStudent`
- the latter points to individual students represented by URIs
- the former to a *list* of student names in the from of a string

Who has worked with Jeffrey Ullman?

Ullman is *the* most referenced computer scientist

- DBpedia contains info about, e.g. his
  - education and laureates
  - citizenship and nationality
  - scientific contributions
- say we wish to compile a list of his collaborators, including at least
  - advisors, and
  - PhD students

- set relevant prefixes:

```
String ont = "http://dbpedia.org/ontology/";
String res = "http://dbpedia.org/resource/";
String prop = "http://dbpedia.org/property/";
String ex = "http://www.example.org/";
```

- connect to DBpedia, describe J. Ullman:

```
String dbpedia = "http://dbpedia.org/sparql";
String describe = "DESCRIBE <" + res + "Jeffrey_Ullman>";
QueryExecution qexc =
  QueryExecutionFactory.sparqlService(dbpedia, describe);
Model ullman = qexc.execDescribe();
```

- build an ontology of collaborators:

```
Model ontology = ModelFactory.createDefaultModel();
Property collab = ontology.createProperty(ex + "Collaborator");
Property phds = ontology.createProperty(prop + "doctoralStudents");
Property phd = ontology.createProperty(ont + "doctoralStudent");
Property adv = ontology.createProperty(ont + "doctoralAdvisor");
ontology.add(phds, RDFS.subPropertyOf, collab);
ontology.add(phd, RDFS.subPropertyOf, collab);
ontology.add(adv, RDFS.subPropertyOf, collab);
```


- build an ontology of collaborators (or better, read it from file):

```
Model ontology = ModelFactory.createDefaultModel();
Property collab = ontology.createProperty(ex + "Collaborator");
Property phds = ontology.createProperty(prop + "doctoralStudents");
Property phd = ontology.createProperty(ont + "doctoralStudent");
Property adv = ontology.createProperty(ont + "doctoralAdvisor");
ontology.add(phds, RDFS.subPropertyOf, collab);
ontology.add(phd, RDFS.subPropertyOf, collab);
ontology.add(adv, RDFS.subPropertyOf, collab);
```

- … and reason over it:

```
InfModel inf;
inf = ModelFactory.createRDFSModel(ontology, ullman);
```

- wrap it in an `OntModel` if you need a richer API

- write the query:

```
String qStr =
"PREFIX ont:  <" + ont + ">" +
"PREFIX res:  <" + res + ">" +
"PREFIX ex:  <" + ex + ">" +
"SELECT ?collaborator WHERE {" +
" res:Jeffrey_Ullman ex:Collaborator ?collaborator." +
"}";
```

- execute it …

```
Query query = QueryFactory.create(qStr);
QueryExecution qe = QueryExecutionFactory.create(query, inf);
ResultSet res = qe.execSelect();
```

- and, if, you like, print out the results

```
ResultSetFormatter.out(res, query);
```


An exercise for the reader …

- substituting Pellet for the RDFS reasoner yields a different result
- reason rooted in the respective ‘philosophies’ of RDFS and OWL
- tracking it down, is an instructive exercise …
- which is left for the student

Backwards reasoning over the same example

- bakcwards reasoning often suitable for stuff in memory
- you need a reasoner capable of doing backwards reasoning
- i.e. a rule reasoner
- and a way to configure it
- let's use the built-in `RDFSRuleReasoner`
- first create a configuration specification:

```
# A config spec is itself an RDF graph
Resource config = ontology.createResource();
```


- `ReasonerVocabulary` holds terms for configuration purposes:

```
config.addProperty(ReasonerVocabulary.PROPruleMode, "backward");
```

- now create a rule reasoner and pass it the configuration

```
Reasoner r;
r = RDFSRuleReasonerFactory.theInstance().create(config);
```

- proceed as before ...