TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Informatik, Institut Künstliche Intelligenz, Professur Computational Logic

Schema-Agnostic Query Rewriting in SPARQL 1.1

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Plain Query Answering

Ontological Query Answering

Views on Ontological Query Answering

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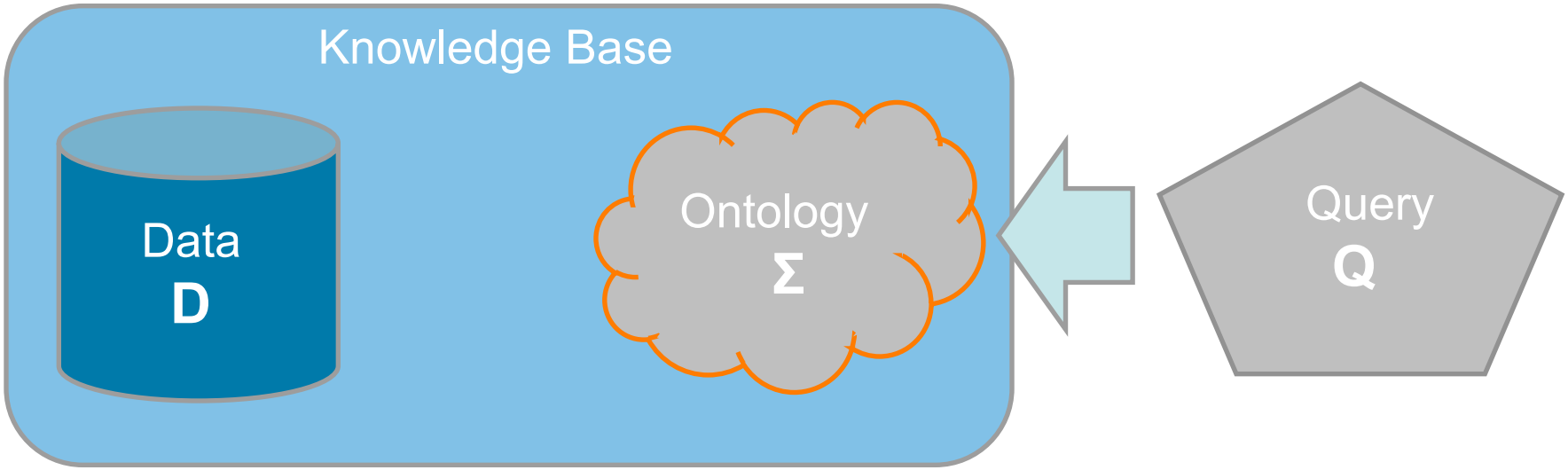
The Knowledge Representation View:



Views on Ontological Query Answering

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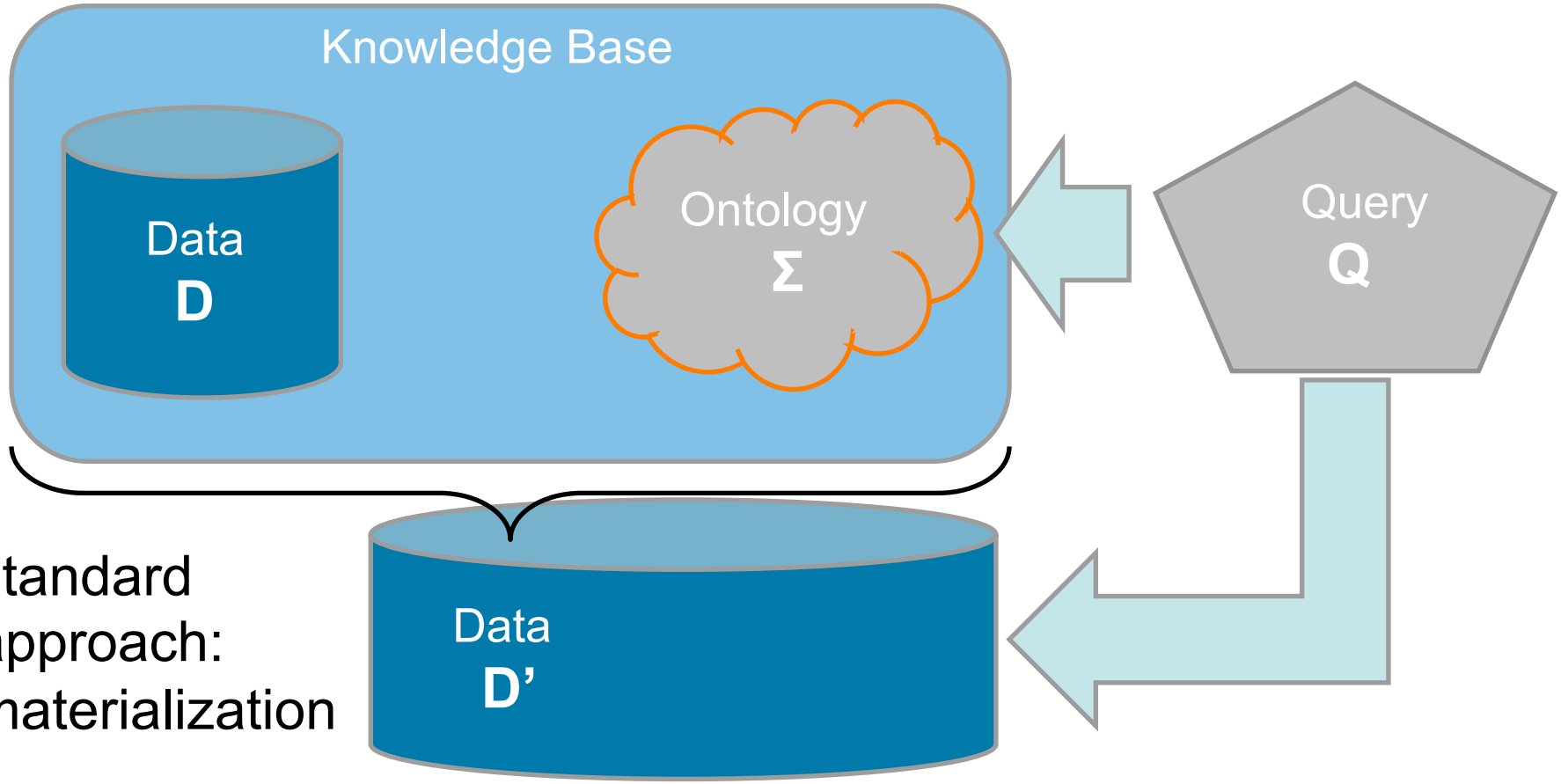

standard approach: materialization

Ontological Query Answering

Views on Ontological Query Answering

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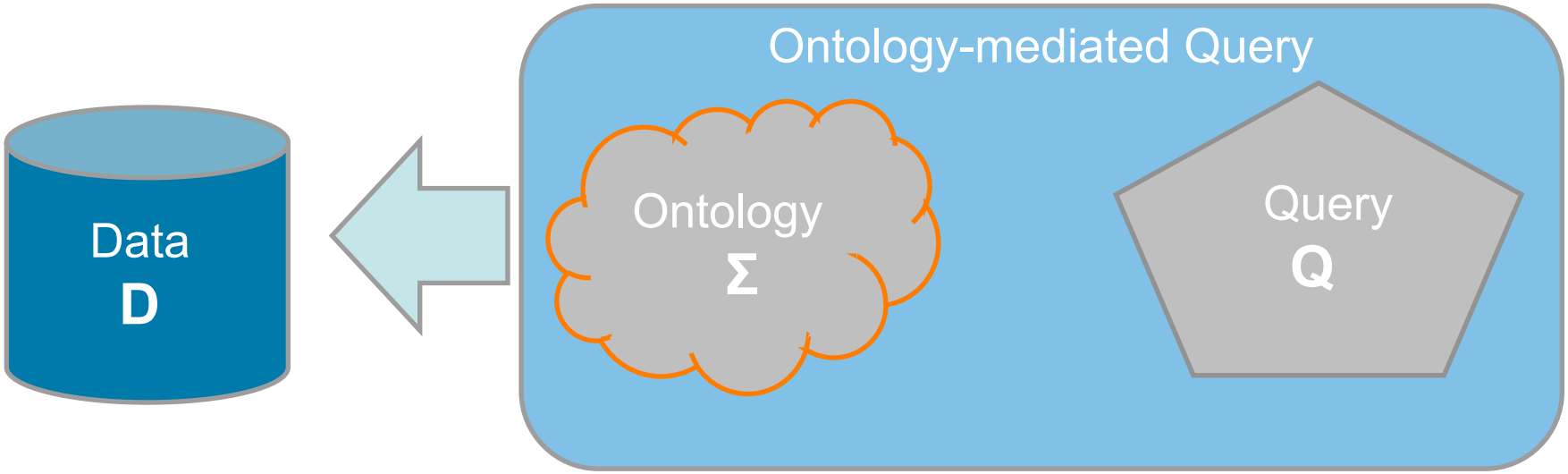
The Database View:



Views on Ontological Query Answering

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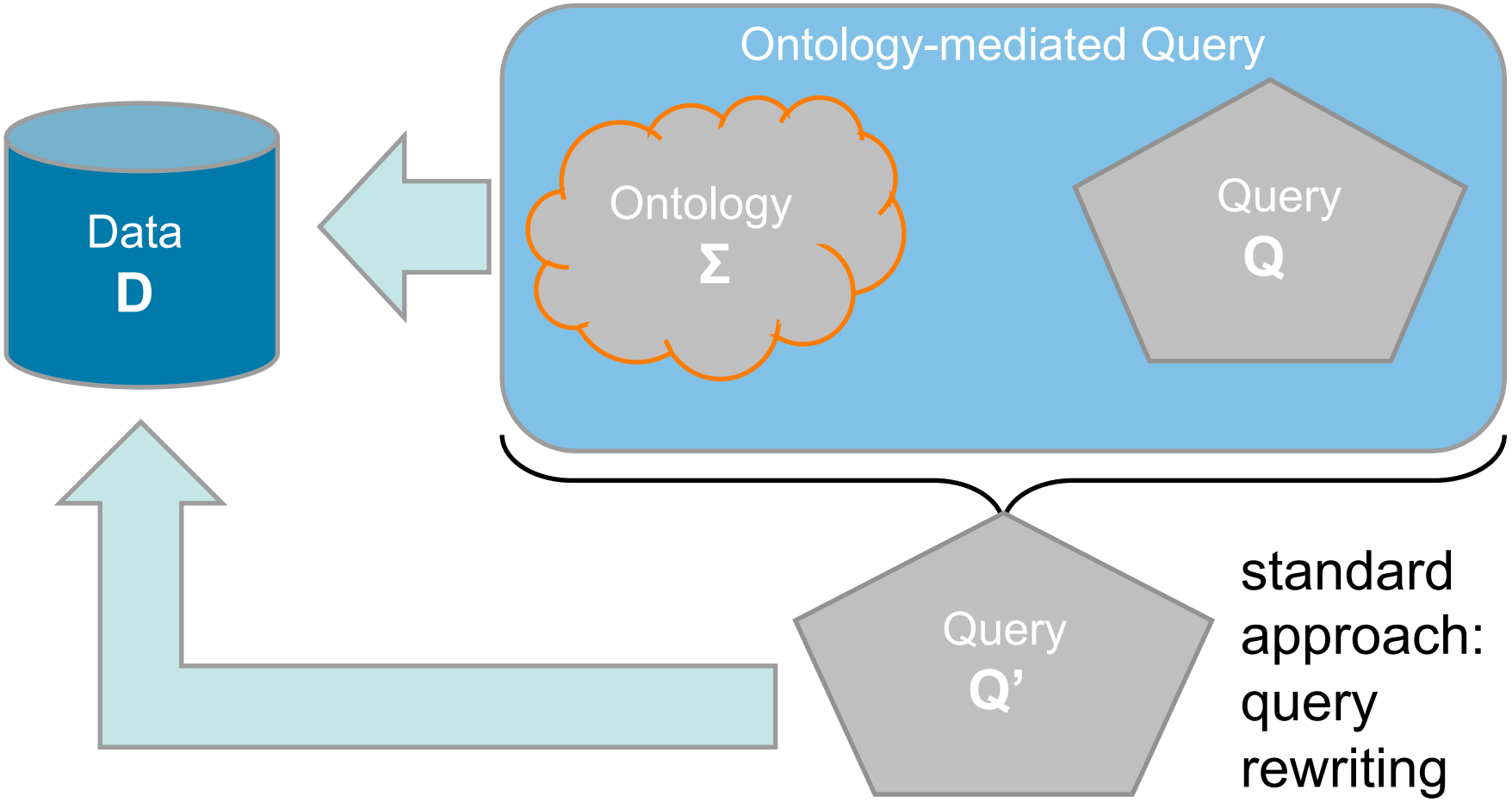
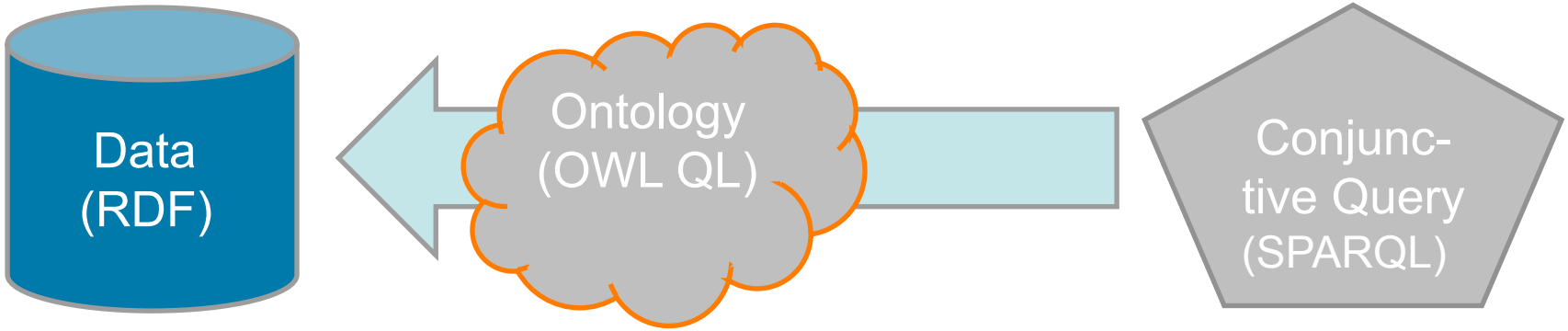
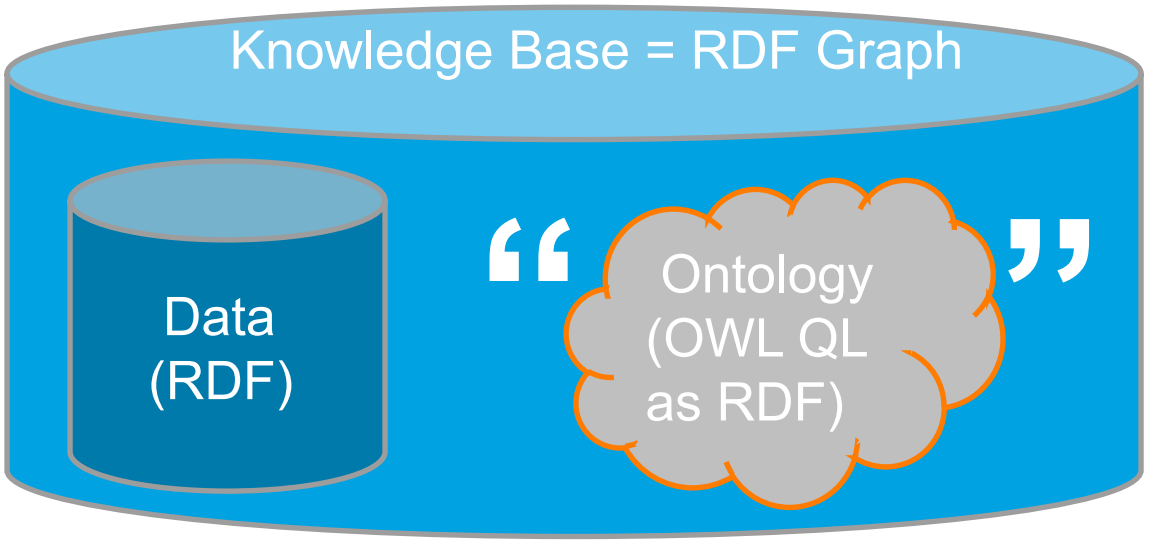


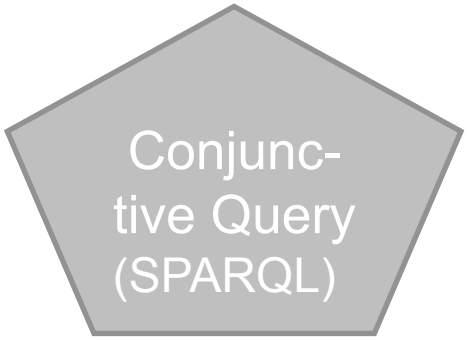
Our Scenario: CQs over OWL QL



- OWL QL based on DL-Lite family
- typically used for data-intensive scenarios
- also covers RDFS in standard use
  (i.e. without schema hijacking)

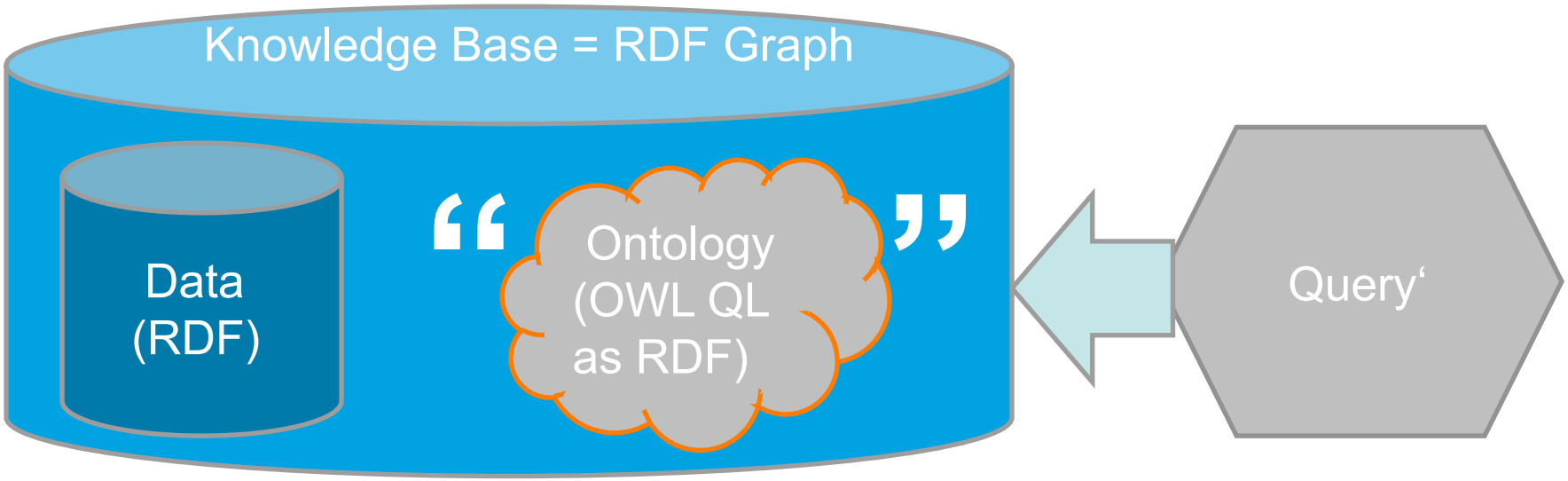
Our Scenario: CQs over OWL QL





- data and schema knowledge all mixed together
- schema knowledge expressed *as data* using special vocabulary: `rdfs:subClassOf`, …
- assumption: RDF Graph not known in advance

Our Scenario: CQs over OWL QL



- data and schema knowledge all mixed together
- schema knowledge expressed *as data* using special vocabulary: `rdfs:subClassOf`, …
- assumption: RDF Graph not known in advance
- Can we still do query rewriting? … Let’s try!

Example

Query: Give me all the individuals known to be persons.

first attempt:

```
SELECT ?p
WHERE ?p rdf:type ex:Person
```

does not work for:

```
ex:shakespeare      rdf:type            ex:Author .
ex:Author           rdfs:subClassOf     ex:Person .
```

Example

Query: Give me all the individuals known to be persons.

second attempt:

```
SELECT ?p
WHERE {?p rdf:type ex:Person} UNION
      {?p rdf:type ?c . ?c rdfs:subClassOf ex:Person}
```

does not work for:

```
ex:shakespeare      rdf:type            ex:Author .
ex:Author           rdfs:subClassOf     ex:Artist .
ex:Artist           rdfs:subClassOf     ex:Person .
```

Example

Query: Give me all the individuals known to be persons.

We need to incorporate arbitrarily long subclass paths.

Use SPARQL 1.1!

```
SELECT ?p
WHERE {?p rdf:type ?c . ?c rdfs:subClassOf* ex:Person}
```

Is this it?

Example

Query: Give me all the individuals known to be persons.

We need to incorporate arbitrarily long subclass paths.

Use SPARQL 1.1!

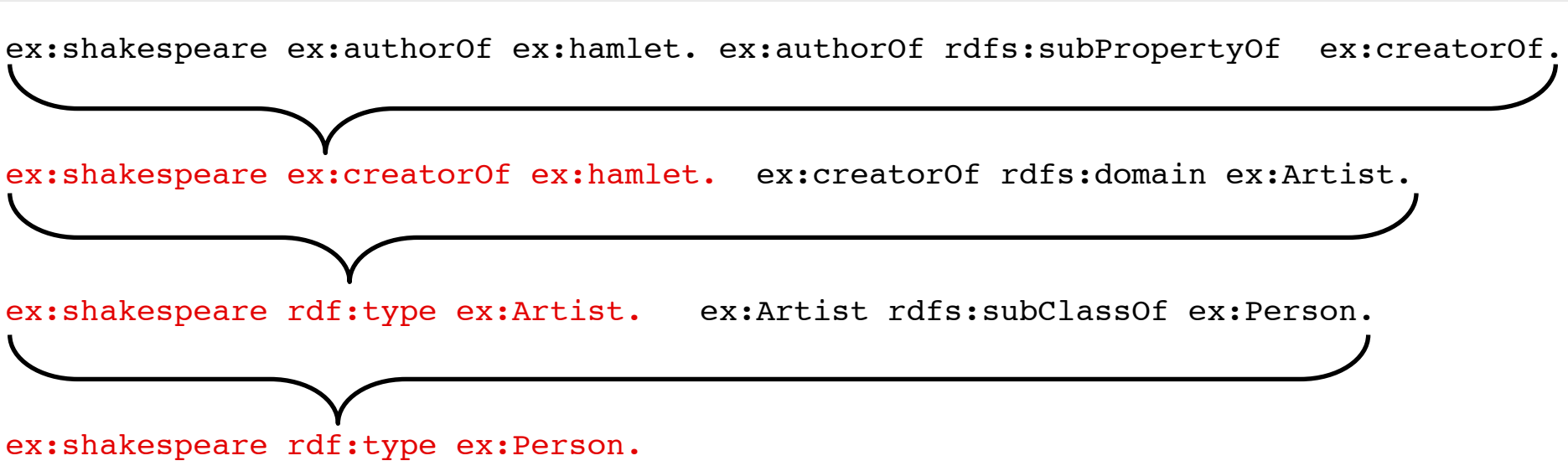
```
SELECT ?p
WHERE {?p rdf:type ?c . ?c rdfs:subClassOf* ex:Person}
```

Is this it? No!

Example

```
ex:shakespeare    ex:authorOf           ex:hamlet .
rdf:authorOf      rdfs:subPropertyOf    ex:creatorOf .
ex:creatorOf      rdfs:domain           ex:Artist .
ex:Artist         rdfs:subClassOf       ex:Person .
```

Example



Important Observations:

- proof tree is linear
- leaf triples in the proof tree form sort of a chain

→ this holds in general

Results (1/2) Rewriting for Single Triples

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Theorem:

For (almost) all OWL QL ontologies, each of the following reasoning tasks can be expressed in a single SPARQL 1.1 query:

- Is the ontology consistent?
- Is the class `A` consistent?
- Does the ontology entail `A rdfs:subClassOf B` ?
- Does the ontology entail `R rdfs:subPropertyOf S` ?
- Does the ontology entail `c rdf:type A` ?
- Does the ontology entail `c R d` ?

Directly extends to schema queries: `A`,`B`,`R`,`S` can be variables!

Example

SPARQL 1.1 query retrieving all inconsistent classes:

```
x (sCO | eqC | ^eqC | intListMember | owl:someValuesFrom |
    (owl:onProperty / (Inv | SpoEqp)* / (^owl:onProperty | rdfs:domain | rdfs:range))* ?C . {
  {?C subClassOf owl:Nothing} UNION
  {?C subClassOf ?D1 {{?C subClassOf ?D2} UNION univClass[?D2]} {
     {?D1 disjointClasses ?D2} UNION
     {?V rdf:type owl:AllDisjointClasses . twoMembers[?V, ?D1, ?D2]}
  }} UNION
  {?C (owl:onProperty / (Inv | SpoEqp)*) ?P . {
     {?P subPropertyOf owl:bottomObjectProperty} UNION
     {?P subPropertyOf ?Q1 {{?P subPropertyOf ?Q2} UNION univProperty[?Q2]} {
        {?Q1 (owl:propertyDisjointWith | ^owl:propertyDisjointWith) ?Q2} UNION
        {?V rdf:type owl:AllDisjointProperties . twoMembers[?V, ?Q1, ?Q2]}
     }
  }}
}
```

Result (2/2) Rewriting for CQs

Theorem: For (almost) all OWL QL ontologies, for all conjunctive queries Q, there is a schema-agnostic SPARQL 1.1 rewriting of linear size.

→ More complicated due to non-distinguished variables

→ Use more SPARQL features: VALUES and FILTER (some guessing involved)

→ Resulting query still of the same complexity as before

First Implementation and Testing

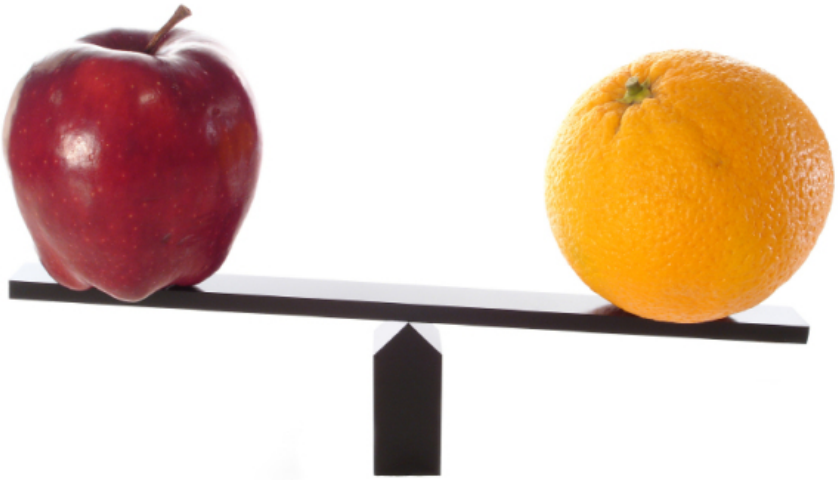
Prototype path rewriter available for download

- Simple web interface and commandline application
- http://stefanbischof.at/publications/iswc14/

First Implementation and Testing

Preliminary evaluation with LUBM and Jena ARQ.

Compared to REQUIEM using QL fragment of the LUBM ontology



- It works!
- Rewriting is always faster than REQUIEM
- Size of rewritings usually smaller than REQUIEM
- Query evaluation is usually slower than REQUIEM

Limits of the Approach

Limit 1: Reasoning complexity

A query language with data complexity C cannot express a reasoning task of combined complexity C' > C.

What does this mean for us?

SPARQL 1.1 is in NLogSpace (data complexity).

Reasoning is PTime-hard for:

OWL EL, OWL RL, RDFS in nonstandard use

→ No schema-agnostic rewriting possible for these cases unless NLogSpace = PTime.

Limits of the Approach

Limit 2: Query expressivity

Query languages usually do not solve all problems of their complexity class – some things might be impossible.

What does this mean for us?

SPARQL 1.1 cannot support owl:SymmetricProperty axioms, although it can support inverse properties.

We require OWL 2 QL with owl:SymmetricProperty paraphrased.

Take-Home Message

Every RDF database featuring SPARQL 1.1 queries can be used as an OWL QL reasoner, with full support for conjunctive queries including schema variables.

Future Work

- Evaluation
- Optimization
  - order of triple patterns impact performance
  - Exploit algebraic equivalences
- Materialize some re-occurring query fragments
  - For example subClassOf “macro”

- What can we do for more expressive ontologies?
  - Combined approaches (touch the data just a little bit)
  - More powerful queries (such as variants of Datalog)

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Thank You!