SPARQL (1): An RDF Query Language

Camilo Thorne

Room 00.012
Institut für Maschinelle Sprachverarbeitung
Universität Stuttgart
+49 (0) 711 685-81369
camilo.thorne@ims.uni-stuttgart.de

Semantic Web, SS 2017

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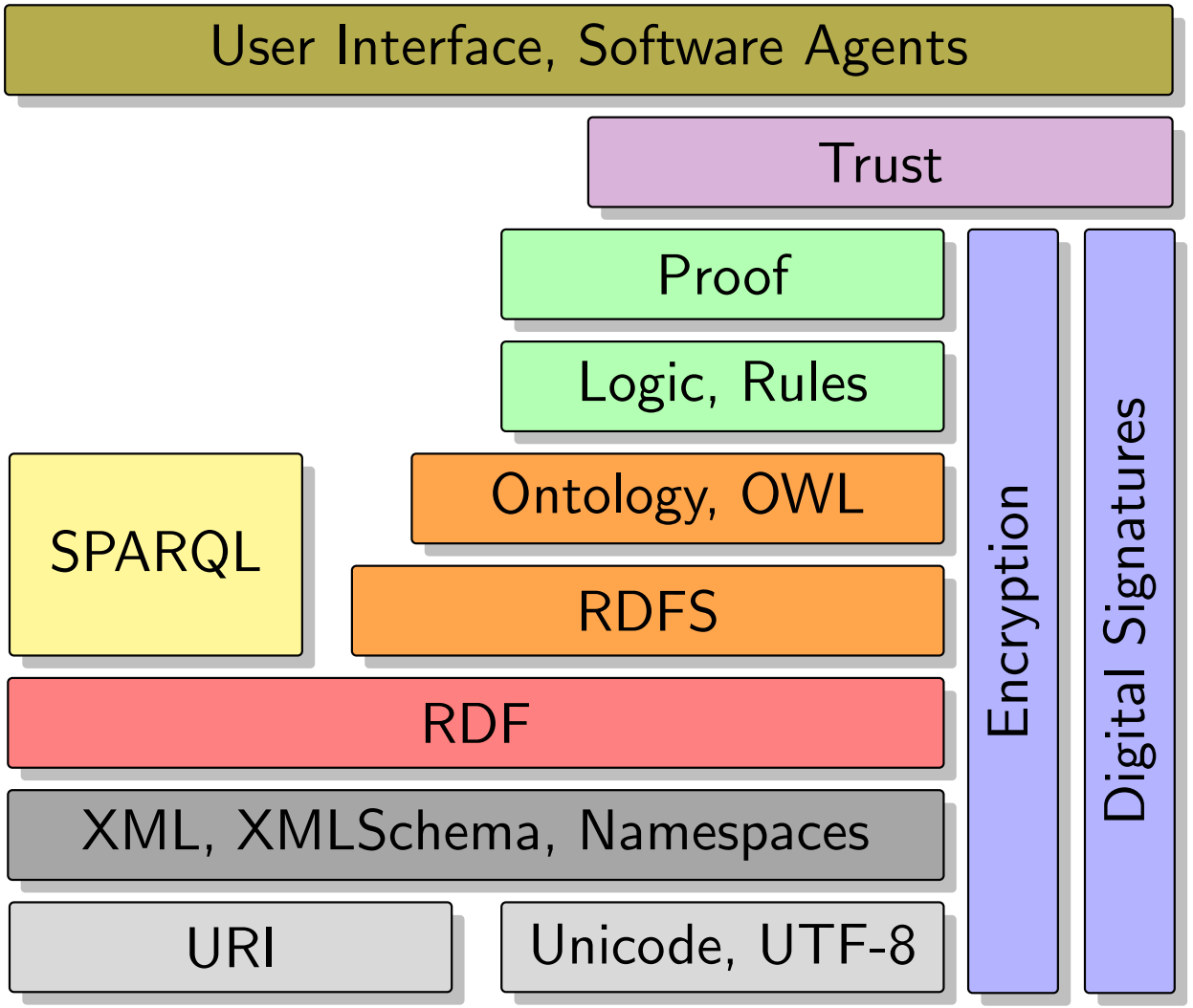
The Semantic Web Stack [W3C, Tim Berners-Lee]



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Outline

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Accessing Information from Ontologies

- We have lots of information in RDF, RDFS
- We can use reasoning to make explicit information implicitly known by an ontology such as
  - What are the instances of class X?
  - Which classes are a subclass of Z?
  - To which classes does x belong?
  - ...

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Accessing Information from Ontologies

- We have lots of information in RDF, RDFS
- We can use reasoning to make explicit information implicitly known by an ontology such as
  - What are the instances of class X?
  - Which classes are a subclass of Z?
  - To which classes does x belong?
  - ...
- But sometimes we want to **retrieve** information stored in an ontology
  - Which German labels are contained in the ontology?
  - Which property connects the individuals x and y?
  - Which two pizzas have a common topping?
  - ...

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SPARQL: SPARQL Protocol and RDF Query Language

- SPARQL is a recursive acronym for "SPARQL Protocol and RDF Query Language"
- SPARQL is pronounced like "sparkle"
- SPARQL is a W3C recommendation since 2008
- SPARQL is used to query RDF(S) (remote) ontologies such as
  - DBpedia: http://dbpedia.org/sparql
  - YAGO: https://linkeddata1.calcul.u-psud.fr/sparql
  - ...
- Apart from the query language we are presenting here, SPARQL is also defines protocols for remote querying ontologies

▷ Inspired by relational DB query languages (= SQL)

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Triplestores and RDF/SPARQL APIs

- Systems supporting SPARQL querying over RDF(S) ontologies are known as **triplestores**:
  - Virtuoso: https://virtuoso.openlinksw.com/
  - Stardog: http://www.stardog.com/
  - Jena: https://jena.apache.org/
  - Ontop: http://ontop.inf.unibz.it/
  - ...
- Several APIs exist to communicate programmatically with triplestores over TCP-IP (and more in general, handle RDF(S) data plus more expressive standards)
  - Apache Jena: https://jena.apache.org/ (Java)
  - SPARQL wrapper: https://rdflib.github.io/sparqlwrapper/ (Python)
  - ...

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SPARQL Basic Syntax

Query composed of:

1. a head:

```
PREFIX p1: <uri1>
...
PREFIX p1: <uri1>
SELECT ?v1 ... ?vn
```

2. a body

```
WHERE{
 C(?v1,...,?vn,?vn+1,...,?vn+m)
}
```

`C[?v1,...,?vn,?vn+1,...,?vn+m]` denotes a sequence of RDF(S) triples; the `?v1,...,?vn` are the answer variables, whereas `?v1,...,?vn` serve to connect triples (join variables)

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SPARQL (Certain Answers) Semantics

Let $\mathcal{O}$ be an RDF(S) ontology. The semantics of a SPARQL query Q with body `C(?v1,...,?vn,?vn+1,...,?vn+m)` is the bag[a] of resources $\{\!|$ `r1`,..., `rn` $|\!\}$ that satisfy the RDF(S) entailment

$$\mathcal{O} \models \texttt{C[?v1,...,?vn,?vn+1,...,?vn+m]}[\texttt{r1,...,rn}/\texttt{?v1,...,?vn}]$$

where

- `?v1,...,?vn` are the head variables (variables we're asking for)
- `?v1,...,?vn` are the join variables (variables used to connect triples in the body)
- $[\texttt{r1,...,rn}/\texttt{?v1,...,?vn}]$ denotes the result of matching resource `ri` to variable `?vi`

[a] A bag $\{\!| \ldots |\!\}$ is a set with repetitions, i.e., $\{\!|a, a|\!\} \neq \{a\}$

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SPARQL Graph/Pattern Matching Semantics

- Certain answers semantics can be characterized (equivalently) as a graph matching task

- SPARQL matches graph patterns in the query with statements that form an RDF graph
- Every match of the query pattern is one returned line
- If the query contains variables, the variables get "bound" to the parts of the triple that correspond to them
- Several patterns are regarded as a conjunction
  (as if connected by `and`)

- We get as answers the same bags $\{\!|$ `r1`,. . . , `rn` $|\!\}$ of resources as with entailments

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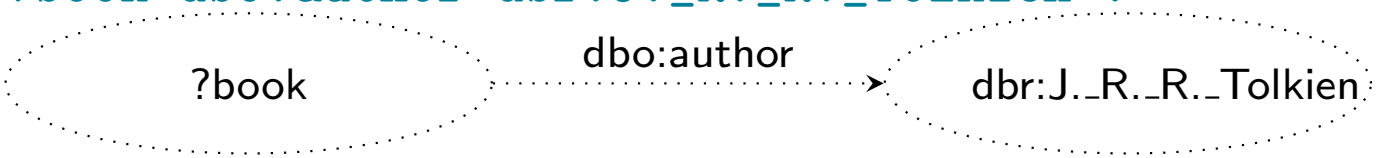
SPARQL Basic Pattern Matching

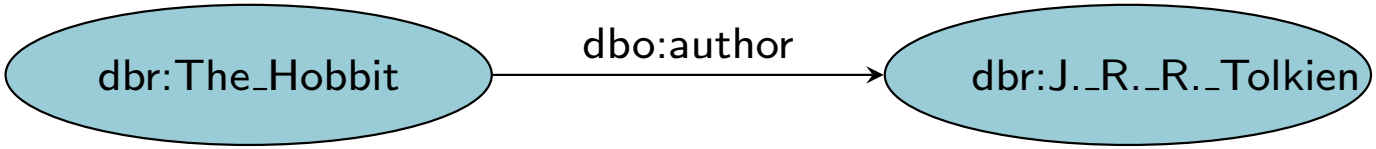
- Example query pattern:

```
?book dbo:author dbr:J._R._R._Tolkien .
```



- Example RDF triple:

```
dbr:The_Hobbit dbo:author dbr:J._R._R._Tolkien .
```



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SPARQL Basic Pattern Matching

- Example query pattern:

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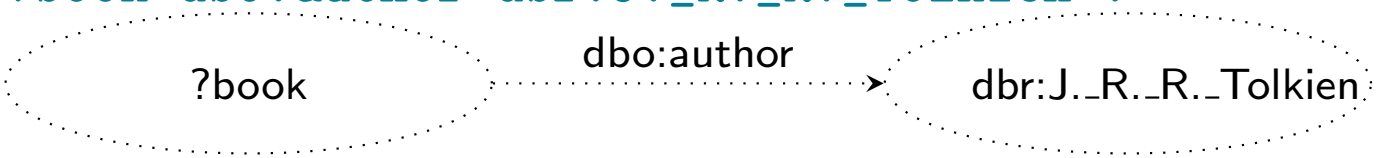
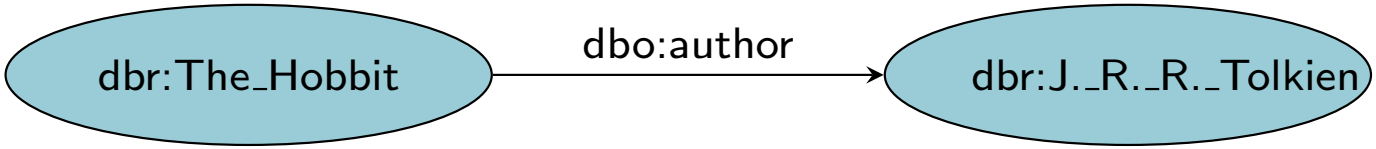
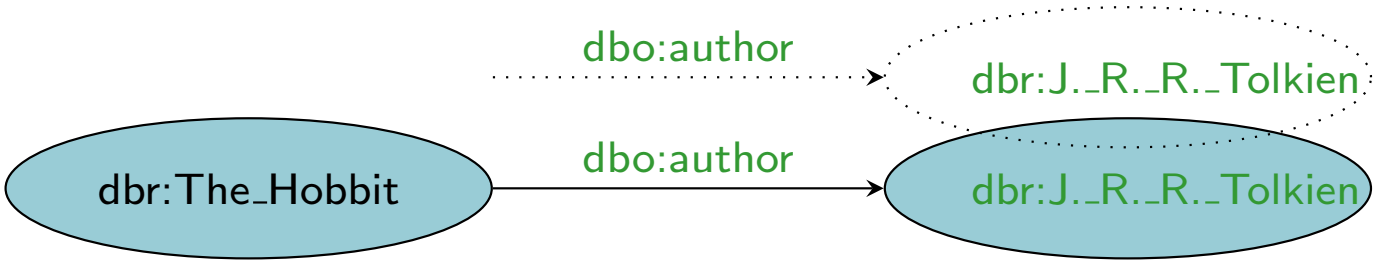


- Example RDF triple:

```
dbr:The_Hobbit dbo:author dbr:J._R._R._Tolkien .
```



- `dbo:author` and `dbr:J._R._R._Tolkien` match,



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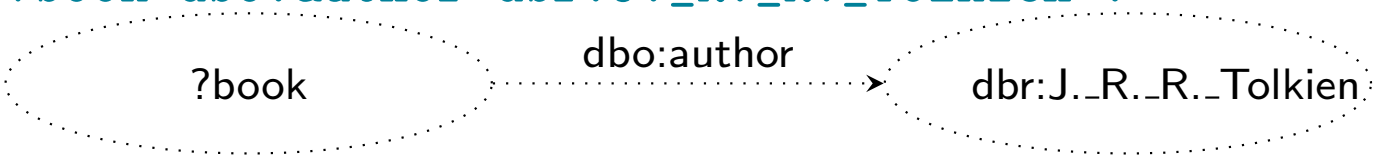
SPARQL Basic Pattern Matching

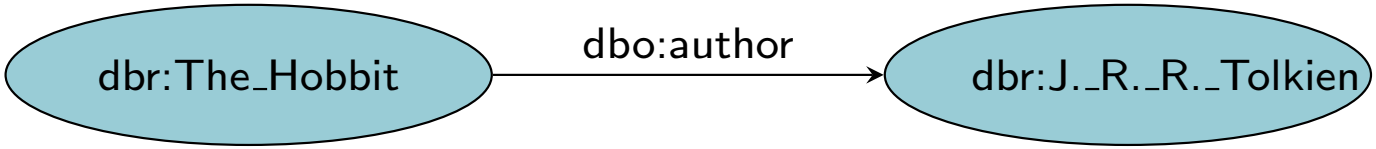
- Example query pattern:

```
?book dbo:author dbr:J._R._R._Tolkien .
```

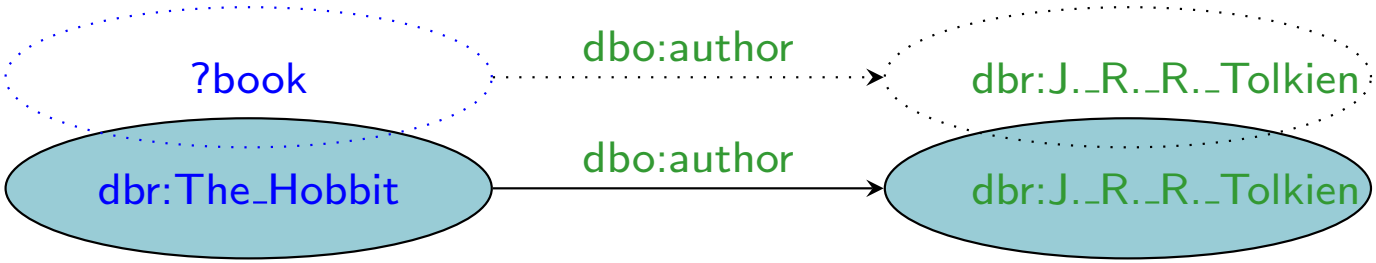


- Example RDF triple:

```
dbr:The_Hobbit dbo:author dbr:J._R._R._Tolkien .
```



- `dbo:author` and `dbr:J._R._R._Tolkien` match, `?book` gets bound to `dbr:The_Hobbit`.



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SPARQL Example (1)

- Query **body**:

```
?book dbo:author ?author .
?author rdf:type ?personclass .
?book dbo:literaryGenre ?genre .
```

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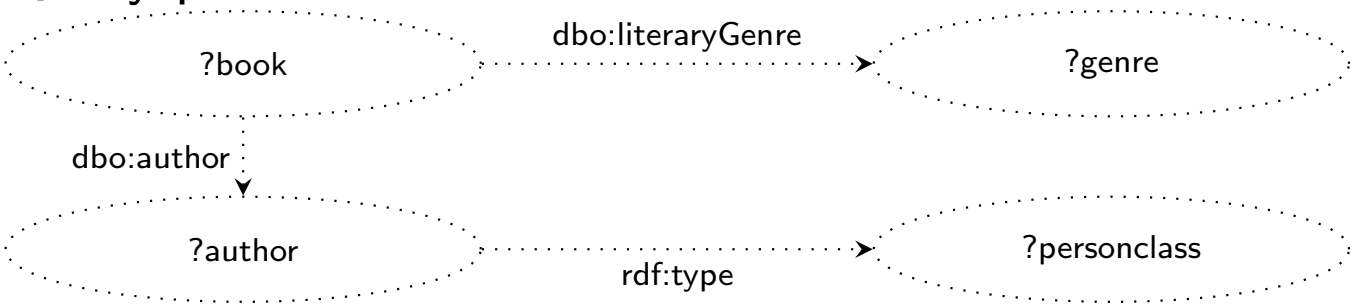
SPARQL Example (1)

- Query **body**:

```
?book dbo:author ?author .
?author rdf:type ?personclass .
?book dbo:literaryGenre ?genre .
```

- Query pattern:



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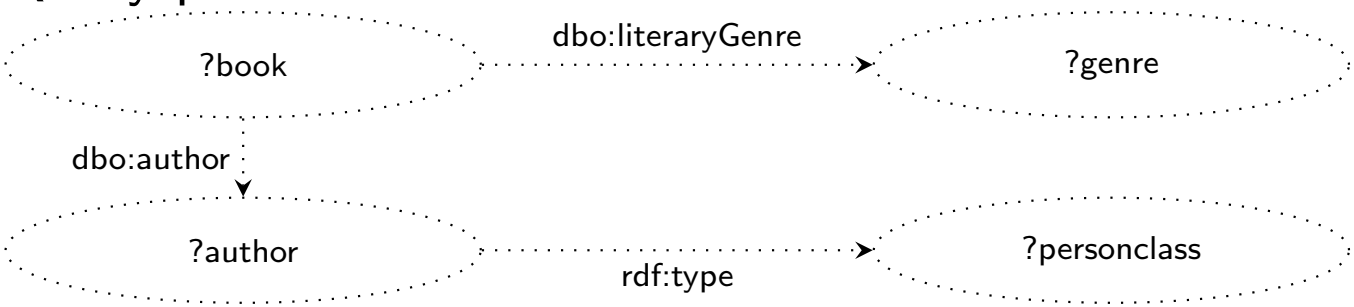
SPARQL Example (1)

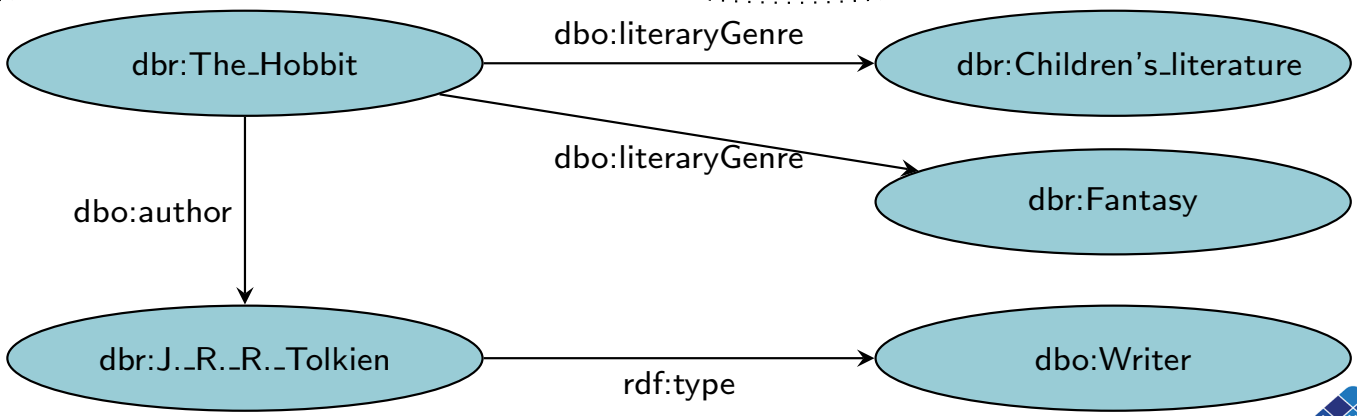
- Query **body**:

```
?book dbo:author ?author .
?author rdf:type ?personclass .
?book dbo:literaryGenre ?genre .
```

- Query pattern:



- RDF graph:



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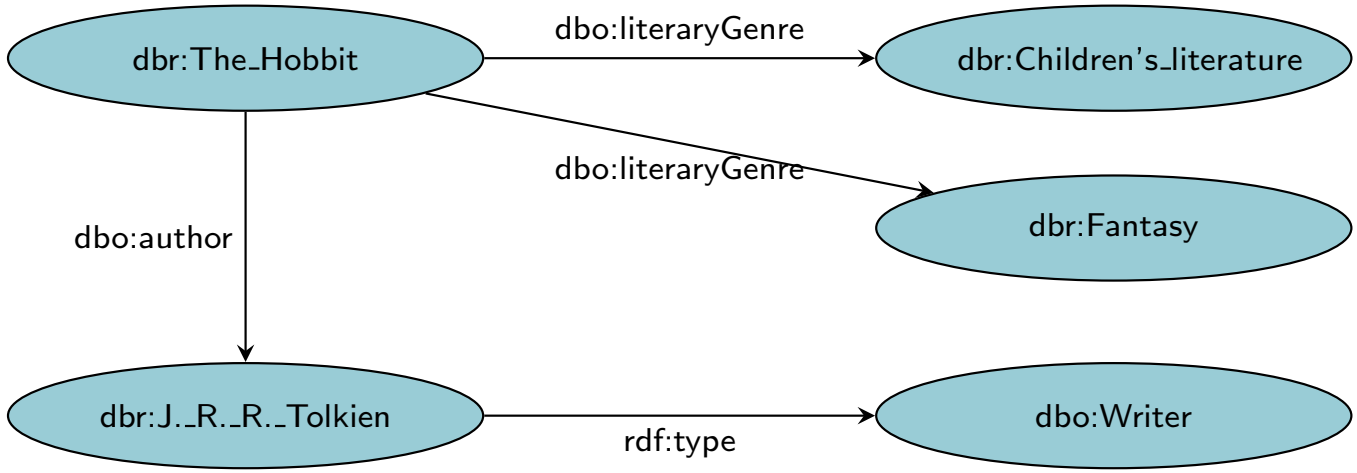
SPARQL Example (2)

- Matching:



- Result:

?book	?author	?personclass	?genre

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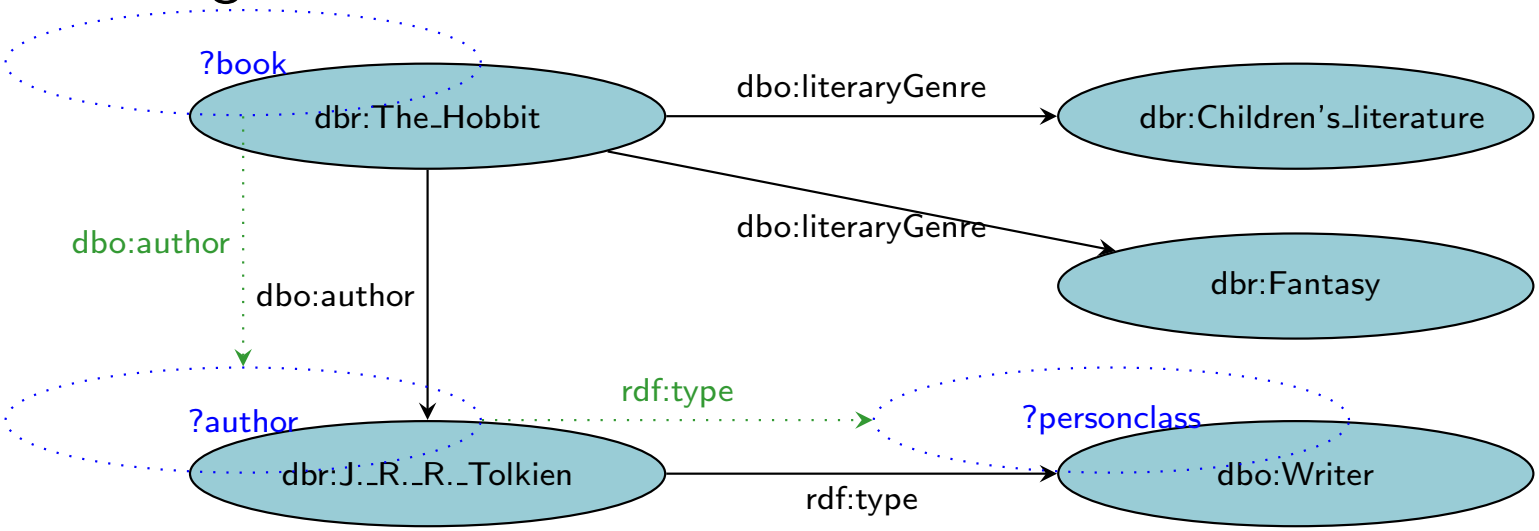
SPARQL Example (2)

- Matching:



- Result:

?book	?author	?personclass	?genre
dbr:The_Hobbit	dbr:J._R._R._Tolkien	dbo:Writer	

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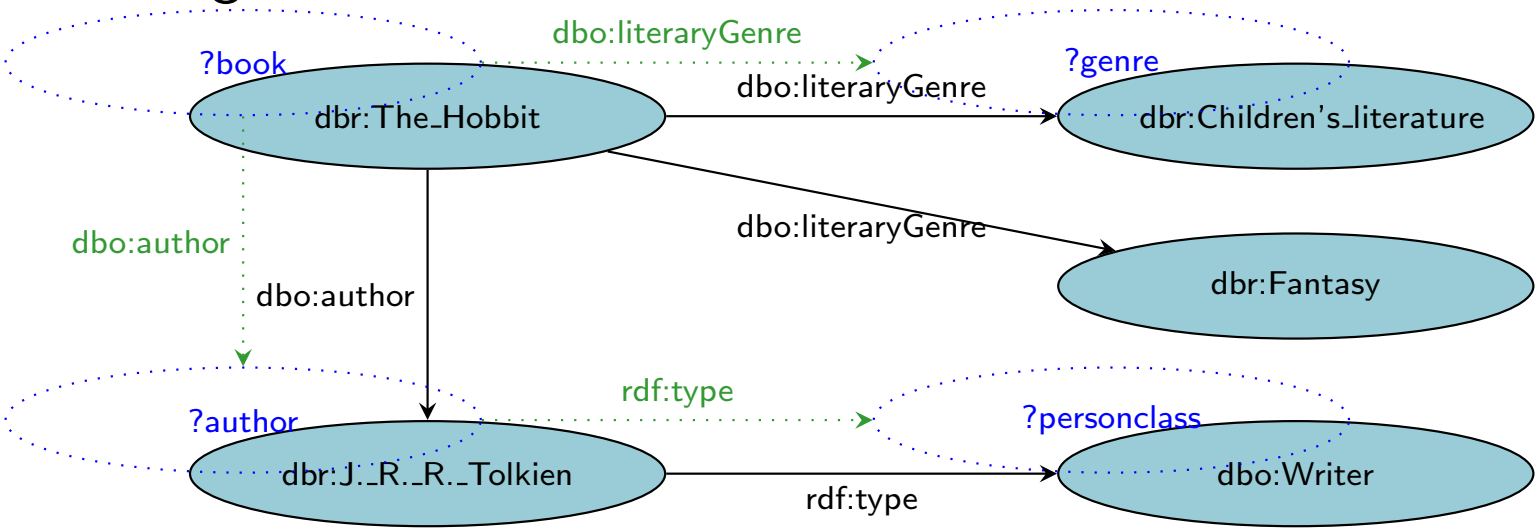
SPARQL Example (2)

- Matching:



- Result:

?book	?author	?personclass	?genre
dbr:The_Hobbit	dbr:J._R._R._Tolkien	dbo:Writer	dbr:Children's_literature

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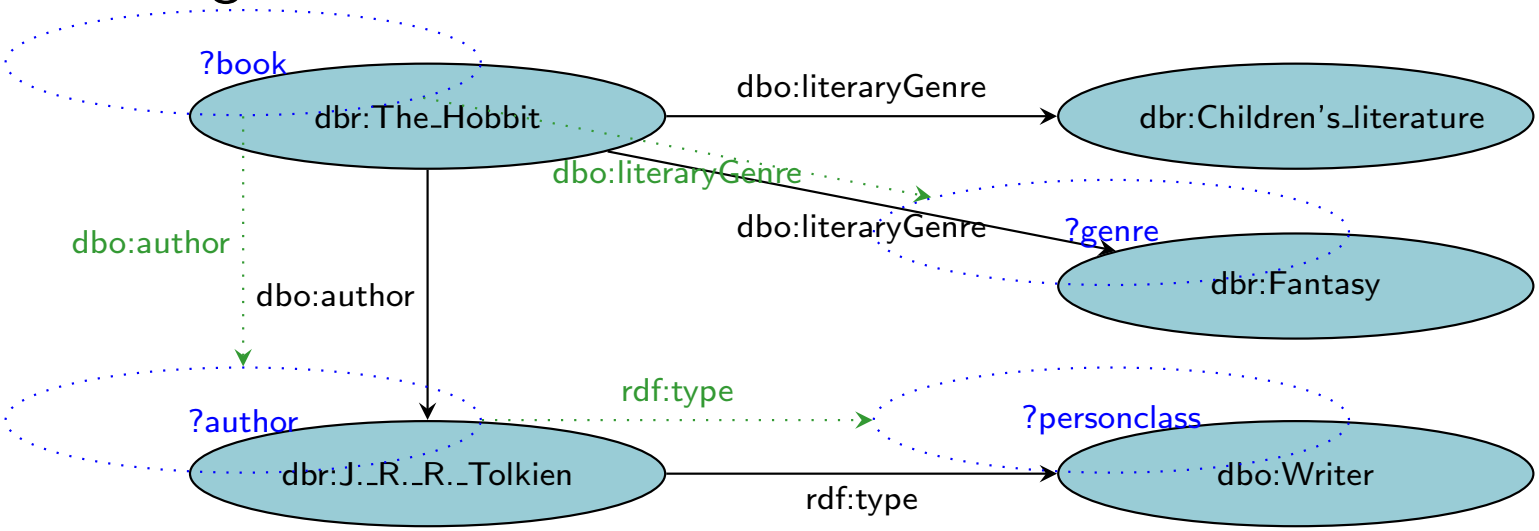
SPARQL Example (2)

- Matching:



- Result:

?book	?author	?personclass	?genre
dbr:The_Hobbit	dbr:J._R._R._Tolkien	dbo:Writer	dbr:Children's_literature
dbr:The_Hobbit	dbr:J._R._R._Tolkien	dbo:Writer	dbr:Fantasy

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SPARQL Example (3)

Complete query[1]:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX dbo: <http://dbpedia.org/ontology/>
SELECT ?book ?author ?personclass ?genre
WHERE {
   ?book dbo:author ?author .
   ?author rdf:type ?personclass .
   ?book dbo:literaryGenre ?genre .
}
```

Result:

?book	?author	?personclass	?genre
dbr:The_Hobbit	dbr:J._R._R._Tolkien	dbo:Writer	dbr:Children's_literature
dbr:The_Hobbit	dbr:J._R._R._Tolkien	dbo:Writer	dbr:Fantasy
dbr:A_Memory_of_Light	dbr:Brandon_Sanderson	dbo:Artist	dbr:Fantasy_literature
dbr:A_Memory_of_Light	dbr:Brandon_Sanderson	dbo:Writer	dbr:Fantasy_literature
...			

[1] Depending on the query interface or **endpoint**, your results will be formatted with prefixes (as in the examples) or as full URIs

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SPARQL Syntax – Prefix

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX dbo: <http://dbpedia.org/ontology/>
```

- `PREFIX` declares a namespace and the abbreviating prefix that can be used to access it.

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SPARQL Syntax – Result Clause

```
SELECT ?book ?author ?personclass ?genre
```

- The result clause identifies what information to return from the query
- Variables are denoted by a `?` in front of the name
- Only the information bound to the variables in the result clause is returned
- The number of lines returned is depending on the number of triples found, each line gives one possible way the variables can be bound to things in the graph

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SPARQL Syntax – Query Patterns

```
WHERE {
   ?book dbo:author ?author .
   ?author rdf:type ?personclass .
   ?book dbo:literaryGenre ?genre .
}
```

- The query pattern is the main part of the SPARQL query
- Query patterns are written in Turtle-Syntax for RDF
- Query patterns are **RDF graph patterns** for statements with subject, predicate and object
- Patterns may contain variables replacing any part of the statement
- Every pattern is terminated by a **dot**
- A sequence of patterns is interpreted as a **conjunction** ($\approx$ relational join)

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SPARQL and Data Types

```
ex:bsp1 ex:p "test" .
ex:bsp2 ex:p "test"^^xsd:string .
ex:bsp3 ex:p "test"@de .
ex:bsp4 ex:p "42"^^xsd:integer .
```

- Remember: Literals are typed in RDF
- SPARQL queries are sensitive to data types, exact matches are necessary
- The query `?subject ex:p "test".` will give `ex:bsp1` as the only result
- To get `ex:bsp3`, the query `?subject ex:p "test"@de .` must be used
- For numbers a short form `?subject ex:p 42 .` is possible, the number is interpreted as `xsd:integer`, `xsd:decimal`, or `xsd:double` according to the surface form

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Quiz: Basic SPARQL Queries

Given are RDF statements about mountains in this form:

```
dbr:Birkenkopf rdf:type dbo:Mountain .
dbr:Birkenkopf dbp:elevationM 511 .
dbr:Birkenkopf dbp:name "Birkenkopf" .
dbr:Birkenkopf dbo:locationArea dbr:Baden-Wurttemberg .
```

Complete the query to retrieve name and height of all mountains:

```
SELECT ?name ?elevation
WHERE {  ...  }
```

A)
```
?name rdfs:subClassOf ?restriction .
?restriction owl:onProperty dbp:elevationM .
?restriction owl:someValuesFrom ?elevation .
```

B)
```
?name rdf:type dbo:Mountain .
?name dbp:elevationM ?elevation .
```

C)
```
?mountain rdf:type dbo:Mountain .
?mountain dbp:elevationM ?elevation .
?mountain dbp:name ?name .
```

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SPARQL Algebra Semantics

- Certain answers semantics can be characterized also in terms of **relational algebra**
- Query answering is based on computing table joins (query body) and projecting away answer columns (query head), e.g., in

```
SELECT ?x WHERE {?x ?y z. ?m ?y z.}
```

  - ▷ triples are interpreted as tables over attributes and values: triple `?x ?y z.` is interpreted as table over columns X, Y and $\{z\}$ with named resource `z` as value z

$$T[X, Y, z]$$

  - ▷ shared (join) variables and resources are interpreted as table joins:

$$T[X, Y, z] \bowtie_{Y,z} T'[M, Y, z]$$

  - ▷ head variables correspond to projections:

$$\pi_X(T[X, Y, z] \bowtie_{Y,z} T'[M, Y, z])$$

- We get again the same bags $\{\!|$ `r1`,. . . , `rn` $|\!\}$ of answers

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Triplestores and Semantics

- Entailment, algebra and pattern matching semantics, while equivalent have different properties
- For us humans, the pattern matching semantics is the easiest to understand
- But in some cases algebra semantics is more computationally efficient, as it leverages relational indexing techniques
- Different triplestores implement different semantics
  - Virtuoso implements the algebra semantics
  - Stardog implements the graph matching semantics
  - Ontop implements the entailment semantics
  - ...
- Which one to choose will depend ultimately in your specific application use case

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Suggested Reading


Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph and York Sure. Semantic Web. Grundlagen. Springer textbook, 2008. (Chapter 7)


Pascal Hitzler, Markus Krötzsch and Sebastian Rudolph. Foundations of Semantic Web Technologies. Chapman & Hall/CRC, 2009. (Chapter 7)

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