Semantic Web Technologies

Topic: SPARQL

Olaf Hartig

olaf.hartig@liu.se

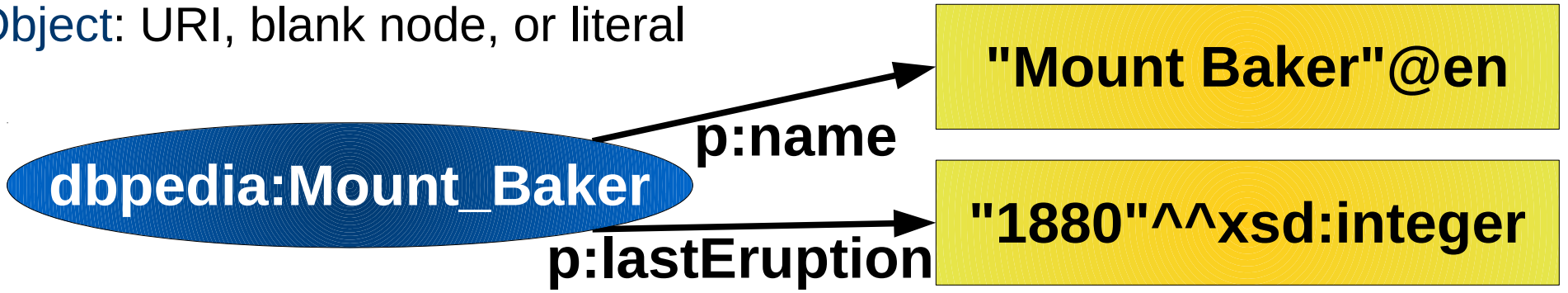
LINKÖPING UNIVERSITY

SPARQL Family of Standards

- Family of W3C recommendations related to querying RDF data
- SPARQL Query Language
  - Declarative query language for RDF data
  - Our focus now
- SPARQL Update
  - Declarative update language for RDF data
- SPARQL Protocol
  - Communication between SPARQL processing services (a.k.a. SPARQL endpoints) and clients
- and more
  - e.g., formats for serializing query results

RDF in a Nutshell

- Data comes as a set of triples (subject, predicate, object)
  - Subject: URI or blank node
  - Predicate: URI
  - Object: URI, blank node, or literal



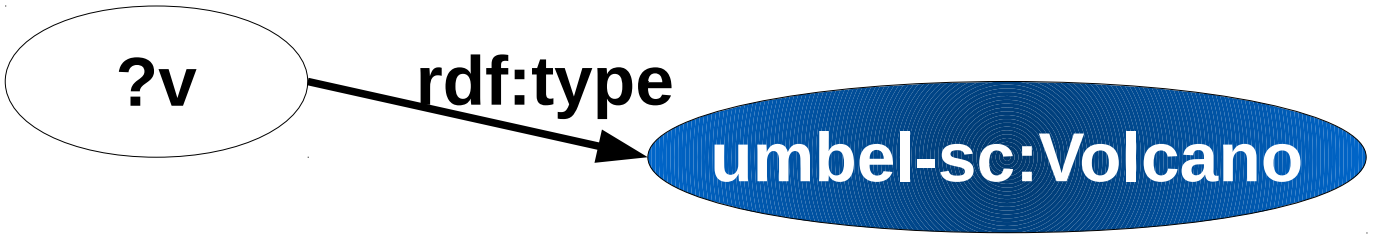

```
@prefix dbpedia : <http://dbpedia.org/resource/> .
@prefix p : <http://dbpedia.org/property/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

dbpedia:Mount_Baker p:lastEruption "1880"^^xsd:integer ;
                    p:location     dbpedia:Washington .
```

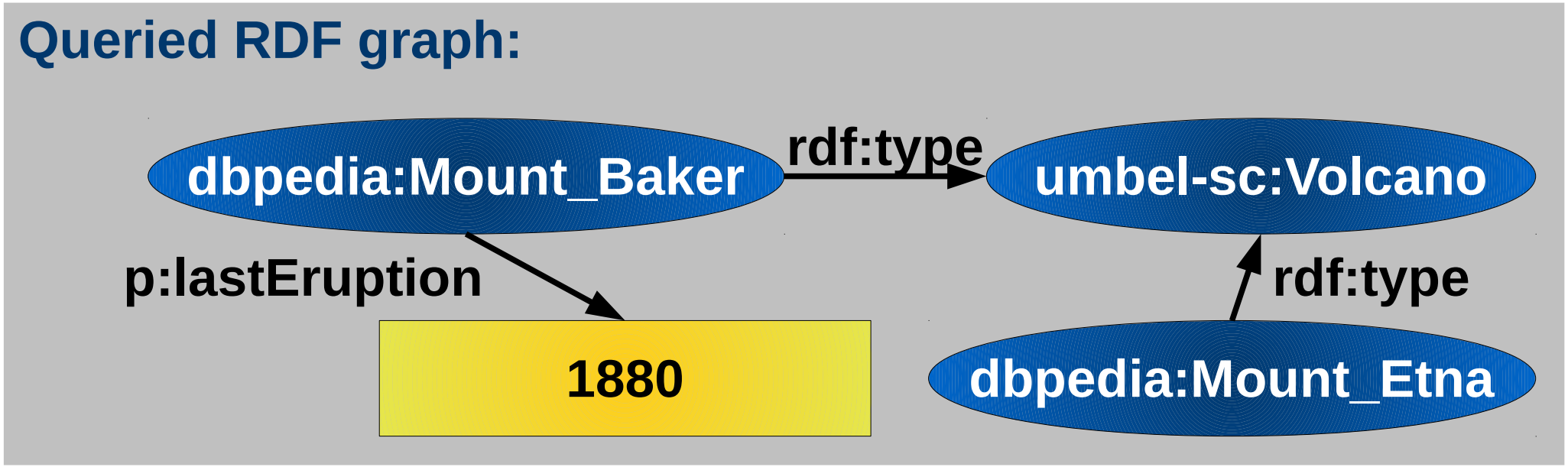
Main Idea of SPARQL Queries

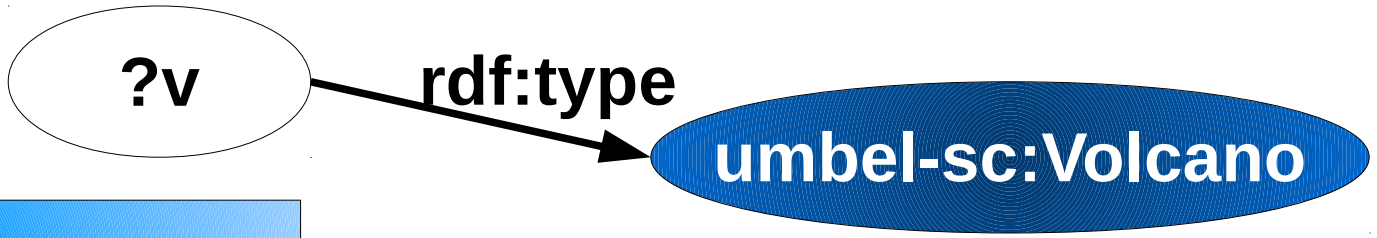
Main Idea of SPARQL Queries

- Pattern matching:
  - Describe subgraphs of the queried RDF graph
  - Subgraphs that match the description yield a result
  - Mean: graph patterns (essentially, RDF graphs with variables)



Main Idea of SPARQL Queries

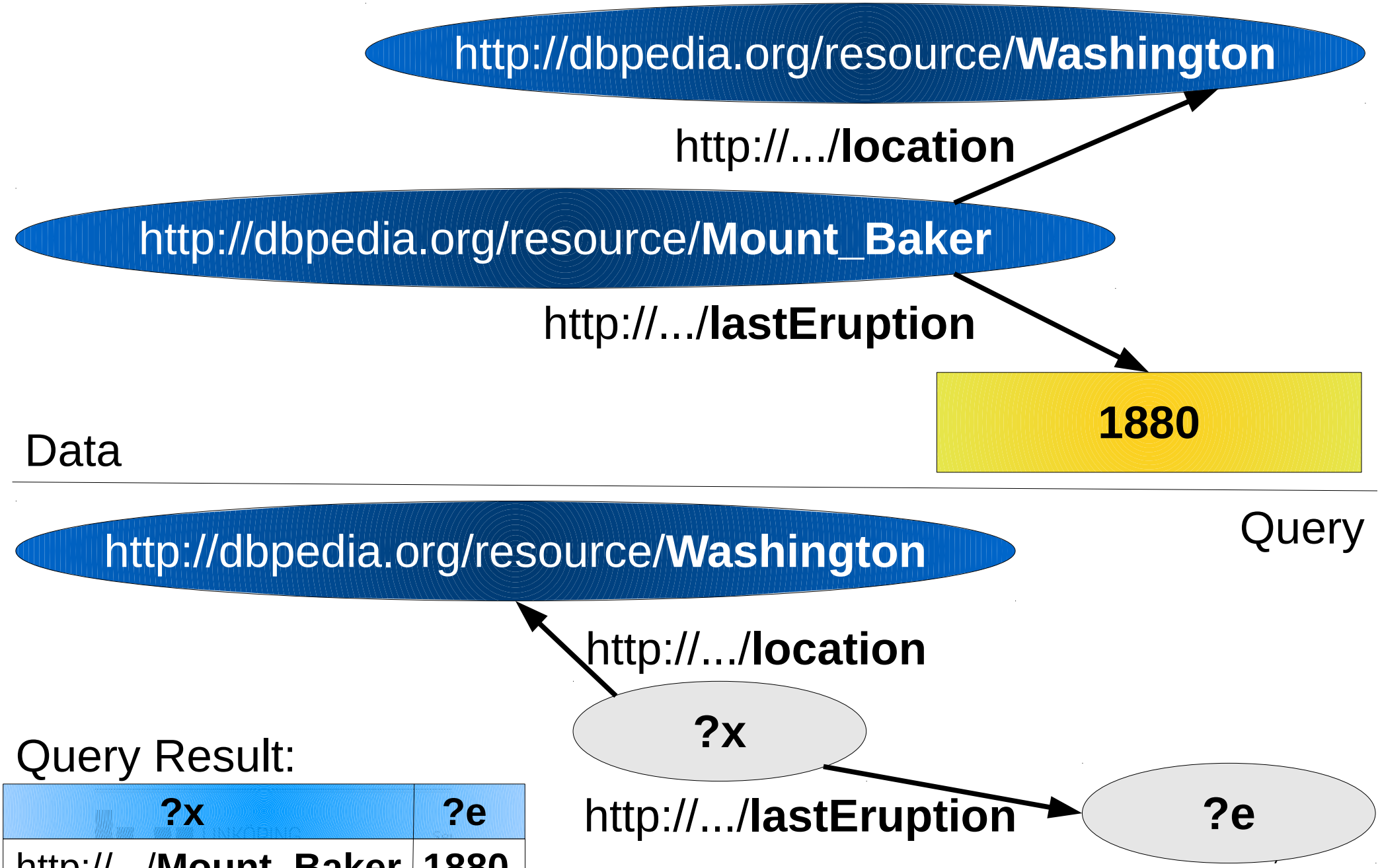




Result:

?v
dbpedia:Mount_Baker
dbpedia:Mount_Etna

Another Example



Query Result:

?x	?e
http://.../Mount_Baker	1880

Components of SPARQL Queries

Components of a SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX umbel-sc: <http://umbel.org/umbel/sc/>
SELECT ?v
FROM <http://example.org/myGeoData>
WHERE {
  ?v rdf:type umbel-sc:Volcano .
}
ORDER BY ?v
```

Components of a SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX umbel-sc: <http://umbel.org/umbel/sc/>
SELECT ?v
FROM <http://example.org/myGeoData>
WHERE {
  ?v rdf:type umbel-sc:Volcano .
}
ORDER BY ?v
```

- Prologue:
  - Prefix definitions for using compact URIs (CURIEs)

Components of a SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX umbel-sc: <http://umbel.org/umbel/sc/>
SELECT ?v
FROM <http://example.org/myGeoData>
WHERE {
  ?v rdf:type umbel-sc:Volcano .
}
ORDER BY ?v
```

- Result form specification:
  - SELECT for projection (similar to SELECT in SQL)
  - Other forms: DESCRIBE, CONSTRUCT, and ASK (more about these later)

Components of a SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX umbel-sc: <http://umbel.org/umbel/sc/>
SELECT ?v
FROM <http://example.org/myGeoData>
WHERE {
  ?v rdf:type umbel-sc:Volcano .
}
ORDER BY ?v
```

- Dataset specification:
  - Specify the RDF dataset to be queried (use URIs that identify particular RDF graphs in your RDF database)

Components of a SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX umbel-sc: <http://umbel.org/umbel/sc/>
SELECT ?v
FROM <http://example.org/myGeoData>
WHERE {
  ?v rdf:type umbel-sc:Volcano .
}
ORDER BY ?v
```

- Query Pattern:
  - WHERE clause specifies the graph pattern to be matched

Components of a SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX umbel-sc: <http://umbel.org/umbel/sc/>
SELECT ?v
FROM <http://example.org/myGeoData>
WHERE {
  ?v rdf:type umbel-sc:Volcano .
}
ORDER BY ?v
```

- Solution modifiers (for SELECT queries):
  - Modify the result set as a whole (not single solutions)
  - Keywords: DISTINCT, ORDER BY, LIMIT, and OFFSET

Simple Types of Graph Patterns

Basic Graph Pattern

- Set of triple patterns (i.e., RDF triples with variables)
- Variable names prefixed with “?” (or “$”)
- Turtle syntax
  - Including syntactic sugar (e.g., property and object lists)

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX umbel-sc: <http://umbel.org/umbel/sc/>
SELECT ?name
WHERE {
  ?v rdf:type umbel-sc:Volcano ;
     rdfs:label ?name .
}
```

Basic Graph Pattern (Example)

Data*

```
dbpedia:Mount_Etna rdf:type umbel-sc:Volcano ;
                   rdfs:label "Etna" .
dbpedia:Mount_Baker rdf:type umbel-sc:Volcano.
dbpedia:Beerenberg rdf:type umbel-sc:Volcano,
                            umbel-sc:NaturalElevation ;
                   rdfs:label "Beerenberg"@en ;
                   rdfs:label "Бееренберг"@ru  .
```

- **Question:** What are the names of all (known) volcanos?

Query*

```
SELECT ?name WHERE {
  ?v rdf:type umbel-sc:Volcano ;
     rdfs:label ?name . }
```

Result:

?name
"Etna"
"Бееренберг"@ru
"Beerenberg"@en

*Prefix declarations omitted

Optional Graph Pattern

Data

```
dbpedia:Mount_Etna rdf:type umbel-sc:Volcano ;
                   rdfs:label "Etna" .
dbpedia:Mount_Baker rdf:type umbel-sc:Volcano .
dbpedia:Beerenberg rdf:type umbel-sc:Volcano ;
                   rdfs:label "Beerenberg"@en .
```

- **Question:** What are *all* (known) volcanos and their names?

Query

```
SELECT ?v ?name WHERE {
  ?v rdf:type umbel-sc:Volcano ;
     rdfs:label ?name . }
```

- **Problem:** Mount Baker missing (b/c no name in the data)

?v	?name
dbpedia:Mount_Etna	"Etna"
dbpedia:Beerenberg	"Beerenberg"@en

Optional Graph Pattern

- Keyword OPTIONAL indicates optional patterns

Query

```
SELECT ?v ?name WHERE {
  ?v rdf:type umbel-sc:Volcano .
  OPTIONAL { ?v rdfs:label ?name }
}
```

?v	?name
dbpedia:Mount_Etna	"Etna"
dbpedia:Mount_Baker	
dbpedia:Beerenberg	"Beerenberg"@en

- Optional patterns may result in unbound variables

UNION Clauses

Data

```
dbpedia:Mount_Etna rdf:type umbel-sc:Volcano ;
                   rdfs:label "Etna" ;
                   p:location dbpedia:Italy .
dbpedia:Mount_Baker rdf:type umbel-sc:Volcano ;
                    p:location dbpedia:United_States .
dbpedia:Beerenberg rdf:type umbel-sc:Volcano ;
                   rdfs:label "Beerenberg"@en ;
                   p:location dbpedia:Norway .
```

Question: Which volcanos are located in the Italy or in Norway?

Query

```
SELECT ?v WHERE {
  ?v rdf:type umbel-sc:Volcano ;
     p:location    ?     . }
```

UNION Clauses

Query

```
SELECT ?v WHERE {
  { ?v rdf:type umbel-sc:Volcano ;
       p:location dbpedia:Italy }
  UNION
  { ?v rdf:type umbel-sc:Volcano ;
       p:location dbpedia:Norway }
}
```

Semantically equivalent

```
SELECT ?v WHERE {
  ?v rdf:type umbel-sc:Volcano .

  { ?v p:location dbpedia:Italy }
  UNION
  { ?v p:location dbpedia:Norway }
}
```

Query

Constraints on Solutions

Constraints on Solutions

- Syntax: Keyword FILTER followed by filter expression

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX umbel-sc: <http://umbel.org/umbel/sc/>
PREFIX p: <http://dbpedia.org/property/>

SELECT ?v
WHERE {
  ?v rdf:type umbel-sc:Volcano ;
     p:lastEruption ?le .
  FILTER ( ?le > 1900 )
}
```

- Filter expressions contain operators and functions

Unary Operators in Constraints

Operator	Type(A)	Result type
! A	xsd:boolean	xsd:boolean
+ A	numeric	numeric
- A	numeric	numeric
BOUND(A)	variable	xsd:boolean
isURI(A)	RDF term	xsd:boolean
isBLANK(A)	RDF term	xsd:boolean
isLITERAL(A)	RDF term	xsd:boolean
STR(A)	literal / URI	simple literal
LANG(A)	literal	simple literal
DATATYPE(A)	literal	simple literal

Binary and Other Operators

- Logical connectives && and ||
  - for xsd:boolean
- Comparison operators =, !=, <, >, <=, and >=
  - for numeric datatypes, xsd:dateTime, xsd:string, xsd:boolean
- Comparison operators = and !=
  - for other datatypes
- Arithmetic operators +, -, *, and / (for numeric datatypes)
- Furthermore:
  - REGEX(*String*,*Pattern*) or REGEX(*String*,*Pattern*,*Flags*)
  - langMATCHES(*A*,*B*)
  - etc.

Constraints (Example)

Data

```
dbpedia:Mount_Etna rdf:type umbel-sc:Volcano ;
                   rdfs:label "Etna" .
dbpedia:Beerenberg rdf:type umbel-sc:Volcano,
                            umbel-sc:NaturalElevation ;
                   rdfs:label "Beerenberg"@en ;
                   rdfs:label "Бееренберг"@ru  .
```

- **Question:** What volcanos have an “e” in their name?

Query

```
SELECT ?v WHERE {
  ?v rdf:type umbel-sc:Volcano ;
     rdfs:label ?name .
  FILTER( REGEX(STR(?name),"e") )
}
```

?v
dbpedia:Beerenberg
dbpedia:Beerenberg

Constraints (Example, cont'd)

Data

```
dbpedia:Mount_Etna rdf:type umbel-sc:Volcano ;
                   rdfs:label "Etna" .
dbpedia:Beerenberg rdf:type umbel-sc:Volcano,
                            umbel-sc:NaturalElevation ;
                   rdfs:label "Beerenberg"@en ;
                   rdfs:label "Бееренберг"@ru  .
```

- **Question:** What volcanos have an "e" in their name?

Query

```
SELECT ?v WHERE {
  ?v rdf:type umbel-sc:Volcano ;
     rdfs:label ?name .
  FILTER( REGEX(STR(?name),"e","i") )
}
```

?v
dbpedia:Mount_Etna
dbpedia:Beerenberg
dbpedia:Beerenberg

Querying RDF Datasets

that contain Named Graphs

Idea

- SPARQL queries are evaluated over an RDF dataset
- An RDF dataset consists of:
  - one default graph and
  - zero or more named graphs (identified by an URI)
- Keyword GRAPH makes one of the named graphs the active graph used for pattern matching

Examples of GRAPH Clauses

```
dbpedia:Mount_Etna rdfs:seeAlso <http://example.org/d1>.
dbpedia:Mount_Baker rdfs:seeAlso <http://example.org/d2>.
```

Default Graph

```
dbpedia:Mount_Etna    http://example.org/d1
    rdf:type umbel-sc:Volcano ;
    rdfs:label "Etna" .
```

```
dbpedia:Mount_Baker   http://example.org/d2
    rdf:type umbel-sc:Volcano .
```

```
dbpedia:Beerenberg    http://example.org/d3
    rdf:type umbel-sc:Volcano ;
    rdfs:label "Beerenberg"@en .
```

Examples of GRAPH Clauses

```
dbpedia:Mount_Etna rdfs:seeAlso <http://example.org/d1>.
dbpedia:Mount_Baker rdfs:seeAlso <http://example.org/d2>.
```

Default Graph

```
dbpedia:Mount_Etna      http://example.org/d1
      rdf:type umbel-sc:Volcano ;
      rdfs:label "Etna" .
```

```
dbpedia:Mount_Baker     http://example.org/d2
      rdf:type umbel-sc:Volcano .
```

```
                                  http://example.org/d3
el-sc:Volcano ;
Beerenberg"@en .
```

```
SELECT ?v WHERE {
  GRAPH <http://example.org/d1> {
    ?v rdf:type umbel-sc:Volcano .
  }
}
```

?v
dbpedia:Mount_Etna

Examples of GRAPH Clauses

```
dbpedia:Mount_Etna rdfs:seeAlso <http://example.org/d1>.
dbpedia:Mount_Baker rdfs:seeAlso <http://example.org/d2>.
```

Default Graph

```
dbpedia:Mount_Etna        http://example.org/d1
     rdf:type umbel-sc:Volcano ;
     rdfs:label "Etna" .
```

```
dbpedia:Mount_Baker       http://example.org/d2
     rdf:type umbel-sc:Volcano .
```

http://example.org/d3

```
SELECT ?v WHERE {
  GRAPH ?g {
    ?v rdf:type umbel-sc:Volcano .
  }
}
```

?v
dbpedia:Mount_Etna
dbpedia:Mount_Baker
dbpedia:Beerenberg

Examples of GRAPH Clauses

```
dbpedia:Mount_Etna rdfs:seeAlso <http://example.org/d1>.
dbpedia:Mount_Baker rdfs:seeAlso <http://example.org/d2>.
```

Default Graph

```
dbpedia:Mount_Etna      http://example.org/d1
     rdf:type umbel-sc:Volcano ;
     rdfs:label "Etna" .
```

```
dbpedia:Mount_Baker     http://example.org/d2
     rdf:type umbel-sc:Volcano .
```

http://example.org/d3

```
SELECT ?g ?v WHERE {
  GRAPH ?g {
    ?v rdf:type
  }
}
```

?g	?v
<http://example.org/d1>	dbpedia:Mount_Etna
<http://example.org/d2>	dbpedia:Mount_Baker
<http://example.org/d3>	dbpedia:Beerenberg

Examples of GRAPH Clauses

```
dbpedia:Mount_Etna rdfs:seeAlso <http://example.org/d1>.
dbpedia:Mount_Baker rdfs:seeAlso <http://example.org/d2>.
```

Default Graph

```
dbpedia:Mount_Etna    http://example.org/d1
     rdf:type umbel-sc:Volcano ;
     rdfs:label "Etna" .
```

```
dbpedia:Mount_Baker   http://example.org/d2
     rdf:type umbel-sc:Volcano .
```

```
SELECT ?v WHERE {
  _:x rdfs:seeAlso ?g
  GRAPH ?g {
    ?v rdf:type umbel-sc:Volcano .
  }
}
```

?v
dbpedia:Mount_Etna
dbpedia:Mount_Baker

Solution Modifiers

DISTINCT

Removes duplicates from the result set

Data

```
dbpedia:Mount_Etna rdf:type umbel-sc:Volcano ;
                   rdfs:label "Etna" .
dbpedia:Mount_Baker rdf:type umbel-sc:Volcano.
dbpedia:Beerenberg rdf:type umbel-sc:Volcano,
                            umbel-sc:NaturalElevation ;
                   rdfs:label "Beerenberg"@en ;
                   rdfs:label "Бееренберг"@ru  .
```

Query

```
SELECT ?type
WHERE { _:x rdf:type ?type }
```

?type
umbel-sc:Volcano
umbel-sc:Volcano
umbel-sc:NaturalElevation
umbel-sc:Volcano

DISTINCT

Removes duplicates from the result set

Data

```
dbpedia:Mount_Etna rdf:type umbel-sc:Volcano ;
                   rdfs:label "Etna" .
dbpedia:Mount_Baker rdf:type umbel-sc:Volcano.
dbpedia:Beerenberg rdf:type umbel-sc:Volcano,
                            umbel-sc:NaturalElevation ;
                   rdfs:label "Beerenberg"@en ;
                   rdfs:label "Бееренберг"@ru  .
```

Query

```
SELECT DISTINCT ?type
WHERE { _:x rdf:type ?type }
```

?type
umbel-sc:Volcano
umbel-sc:NaturalElevation

ORDER BY

Specify an order for the returned solution mappings

Query

```
SELECT ?v WHERE { ?v rdf:type umbel-sc:Volcano ;
                    rdfs:label ?name }
ORDER BY ?name
```

Order for different kinds of elements:
unbound variable < blank node < URI < literal

ASC for ascending (default) and DESC for descending

Hierarchical order criteria:

Query

```
SELECT ?name WHERE { ?v rdf:type umbel-sc:Volcano ;
                       p:lastEruption ?le ;
                       rdfs:label ?name }
ORDER BY DESC(?le), ?name
```

LIMIT and OFFSET

LIMIT – limits the number of solution mappings returned

```
SELECT ?name WHERE { ?v rdf:type umbel-sc:Volcano ;
                       rdfs:label ?name }
ORDER BY ?name
LIMIT 5
```

Query

OFFSET – position/index of the first returned mapping
(useful only in combination with ORDER BY)

```
SELECT ?name WHERE { ?v rdf:type umbel-sc:Volcano ;
                       rdfs:label ?name }
ORDER BY ?name
LIMIT 5 OFFSET 10
```

Query

Result Forms

Components of a SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX umbel-sc: <http://umbel.org/umbel/sc/>
SELECT ?v
FROM <http://example.org/myGeoData>
WHERE {
  ?v rdf:type umbel-sc:Volcano .
}
ORDER BY ?v
```

- Result form specification:
  - SELECT for projection (similar to SELECT in SQL)
  - Other forms: DESCRIBE, CONSTRUCT, and ASK

~~(more about these later)~~ **now ...**

SELECT and ASK

SELECT

- Sequence of solutions mappings
- Selected variables separated by space (not by comma!)
- Asterisk (“*”) character selects all variables in the pattern

ASK

- Check if there is at least one solution mapping
- Example: Do we have any volcanos?

Query

```
ASK WHERE { ?v rdf:type umbel-sc:Volcano .
            OPTIONAL { ?v rdfs:label ?name }
            FILTER( ! BOUND(?name) )
}
```

DESCRIBE

Returns an RDF graph with data about resources

Not deterministic (i.e. query processor determines the actual structure of the returned RDF graph)

Name the resource:

```
DESCRIBE <http://dbpedia.org/resource/Beerenberg>
```
Query

Specify the resource with a query pattern:

```
DESCRIBE ?v WHERE {
  ?v rdf:type umbel-sc:Volcano ; rdfs:label ?name .
  FILTER ( STR(?name) = "Beerenberg" )
}
```
Query

Multiple variables possible or asterisk (“*”) for all

CONSTRUCT

Returns an RDF graph created from a template

Template: graph pattern with variables from the query pattern

Query

```
CONSTRUCT { ?v rdfs:label ?name ;
                  rdf:type myTypes:VolcanoInTheUS }
WHERE {
  ?v rdf:type umbel-sc:Volcano ;
     rdfs:label ?name ;
     p:location ?l .
  FILTER ( ?l = dbpedia:United_States )
}
```

SPARQL Version 1.1

SPARQL 1.1

- New features of SPARQL 1.1 Query:
  - Aggregate functions (e.g., COUNT, SUM, AVG)
  - Sub-queries
  - Negation (EXISTS, NOT EXISTS, MINUS)
  - Assignments (e.g., BIND, SELECT expressions)
  - Property paths (navigation à la XPath)
  - Basic query federation (SERVICE, VALUES)

- SPARQL 1.1 Update:
  - Graph update (INSERT DATA, DELETE DATA, INSERT, DELETE, DELETE WHERE, LOAD, CLEAR)
  - Graph management (CREATE, DROP, COPY, MOVE, ADD)

www.liu.se

LINKÖPING UNIVERSITY