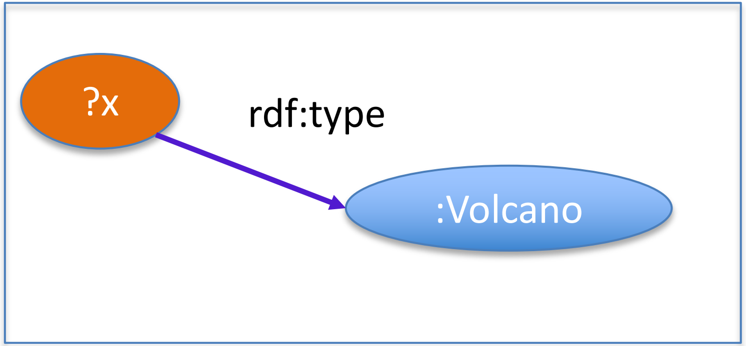
The SPARQL query language for RDF

Gilles Falquet

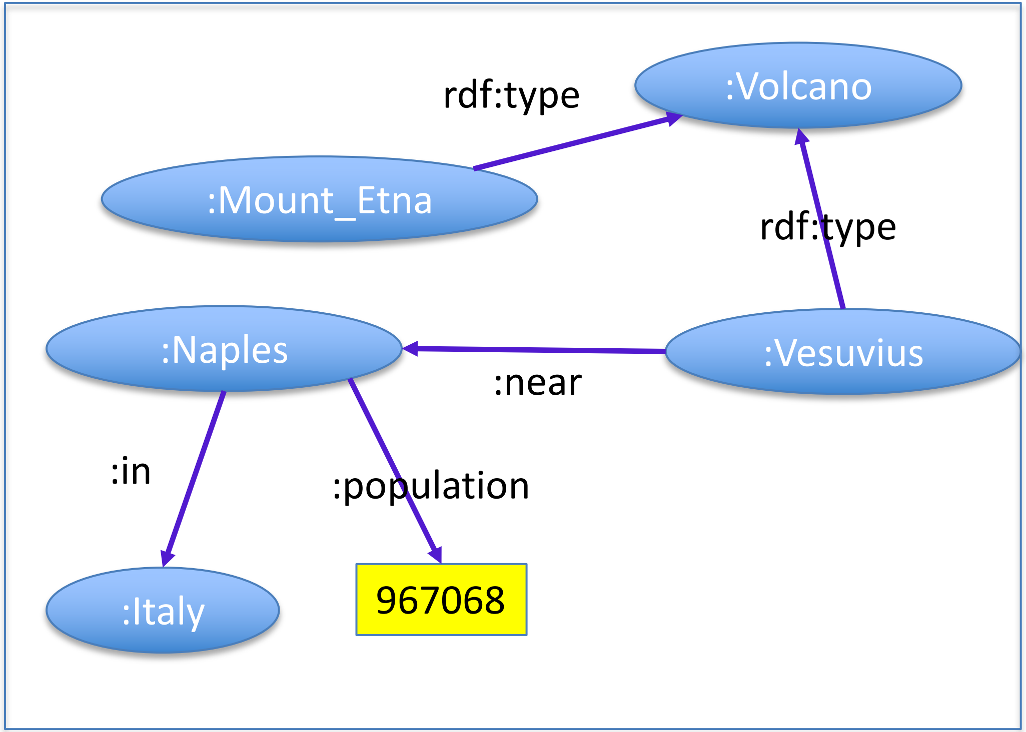
Main idea: Querying by pattern matching



Pattern

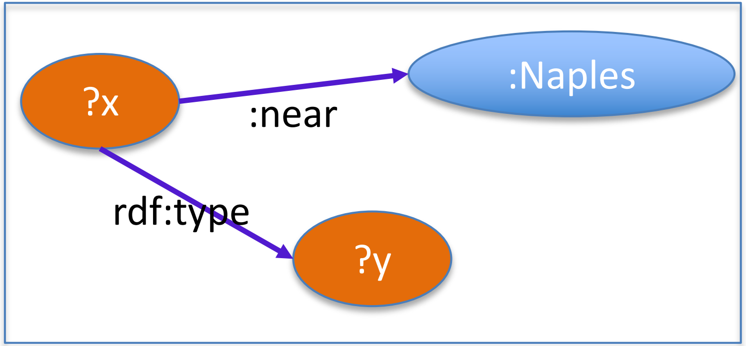
Results

?x
:Vesuvius
:Mount_Etna



Graph

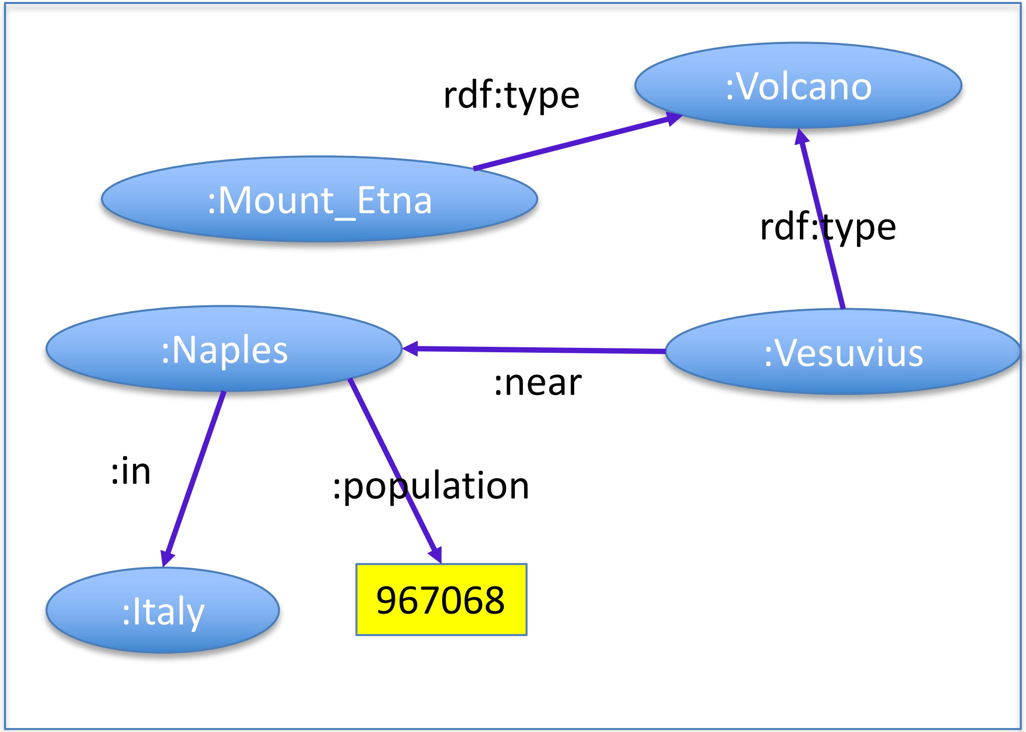
Main idea: Querying by pattern matching



Pattern

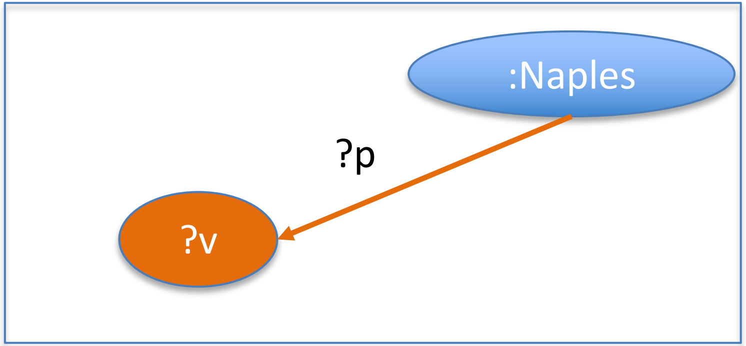
Results

?x	?y
:Vesuvius	:Volcano

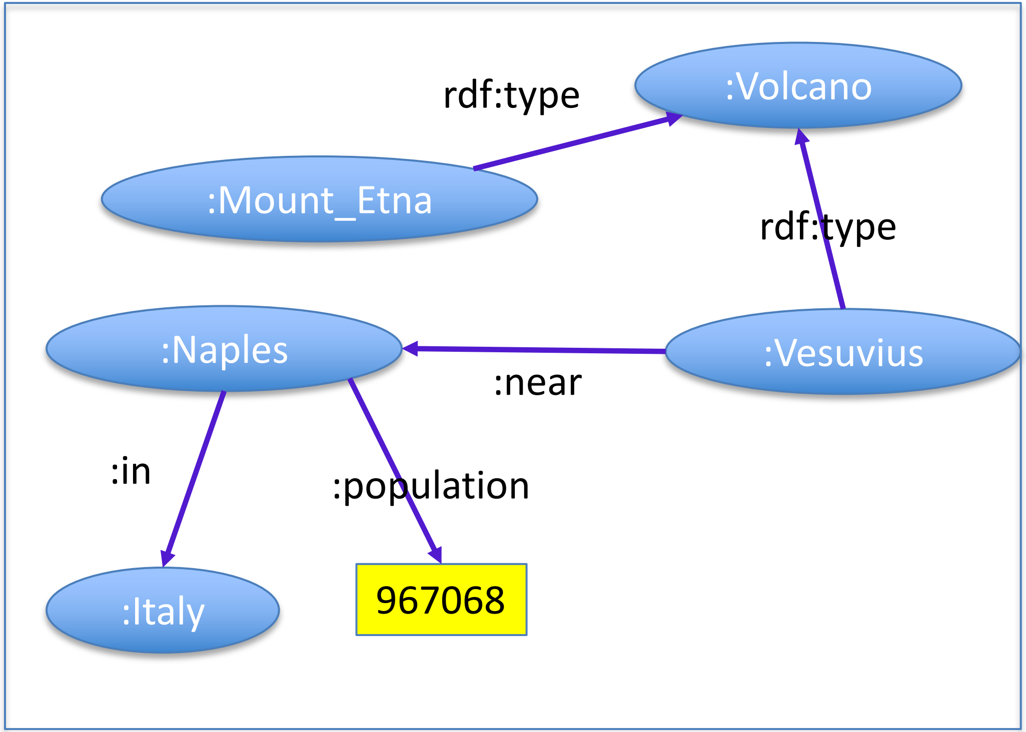


Graph

Main idea: Querying by pattern matching



Pattern



Graph

Results

?p	?v
:in	:Italy
:population	967068

SPARQL – based on graph patterns

Triple pattern a triple from

(RDF-Term ∪ Var) × (IRI ∪ Var) x (RDF-Term ∪ Var)

- RDF-Term : IRI or literal or blank
- Var : variable

Graph pattern

- a set of triple patterns

Same syntax as Turtle + Variables

```
{?x rdf:type :Volcano}
{?x :near :Naples. ?x rdf:tye ?y}
{ :Naples ?p ?v}
{ ?x ex:address _:adr . _:adr ex:city ex:Madrid }
```

SPARQL Basic Graph Pattern Query

prefix definitions
select *output variables*
[from *graph*]
where { *basic graph pattern* }

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX : <http://cui.unige.ch/geo/>
SELECT ?x ?y
WHERE {?x :near :Naples. ?x rdf:tye ?y}
```

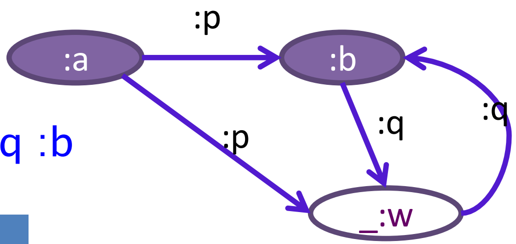
Definition: Basic Graph Pattern Matching

Let BGP be a basic graph pattern and let G be an RDF graph.

μ is a **solution** for BGP from G when

- there is a pattern instance mapping P such that P(BGP) is a subgraph of G
  - P maps variables and blank nodes to RDF-terms
- and μ is the restriction of P to the query variables in BGP.

Example



On the graph

:a :p :b.   :a :p _:w.   :b :q _:w.   _:w :q :b

solutions for { ?x ?y :b }

?x	?y
:a	:p
_:w	:q

solutions for { ?x :p ?y . ?y :q ?z }

?x	?y	?z
:a	:b	_:w
:a	_:w	:b

solutions for { ?x :p _:h . _:h :q ?z }

?x	?z
:a	_:w
:a	:b

Simple Graph Patterns are not Enough

Need to express

- disjunctions (match this or that)
- optional parts in patterns (match if possible)
- negations (match this but not that)
- conditions on variable values (<, >, =, ...)
- multiple paths (path expressions) in patterns

Need to process the results

- combine the solution variables (+, -, ...)
- aggregation functions (sum, average, ...)
- ordering
- grouping

Optional parts

{$pattern_1$ OPTIONAL { $pattern_2$ }}

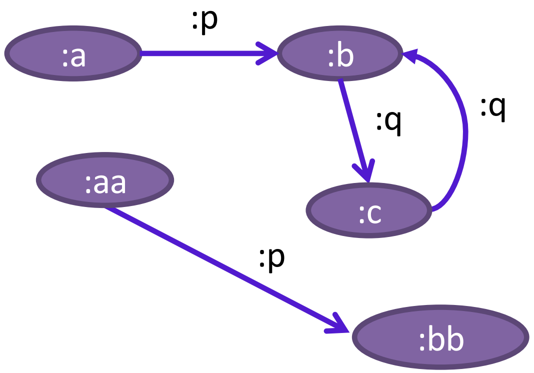
Find solutions for { $pattern_1$ $pattern_2$ } and for { $pattern_1$ }

In the solutions for $pattern_1$ only, the variables that appear in $pattern_2$ only are unbound.

Example

On the graph

:a :p :b.   :aa :p :bb.   :b :q :c.



The solutions of

{ ?x :p ?y OPTIONAL {?y :q ?z} }

are

?x	?y	?z
:a	:b	:c
:aa	:bb	UNBOUND

Union

To represent disjunctions

a solution to

pattern1 UNION *pattern2*

is a solution to *pattern1* or to *pattern2* (or both)

Example

"Find people who own a cat or a dog"

```
{?p a :Person. ?p :owns ?a. ?a a :Cat }
UNION
{?p a :Person. ?p :owns ?a. ?a a :Dog }
```

can be simplified by using group graph patterns

```
{?p a :Person. ?p :owns ?a. {{?a a :Cat} UNION {?a a :Dog}}}
```

Filtering with a boolean exprression

{*pattern* FILTER(*expression*) }

retain only the solutions to *pattern* for which *expression* evaluates to true

Example

```
{ ?x a :Car. ?x :price ?p. ?x :category ?c
        FILTER(?p < 10000 && ?c != :sport) }
```

Testing For the Absence of a Pattern

Data:

```
:alice rdf:type foaf:Person . :alice foaf:name "Alice" .
:bob rdf:type foaf:Person .
```

Query:

```
SELECT ?person
WHERE { ?person rdf:type foaf:Person .
          FILTER NOT EXISTS { ?person foaf:name ?name } }
```

Query Result:

:bob

Testing For the Presence of a Pattern

Query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?person
WHERE { ?person rdf:type foaf:Person .
   FILTER EXISTS { ?person foaf:name ?name } }
```

Query Result:

```
<http://example/alice>
```

Removing Possible Solutions

MINUS evaluates both its arguments, then calculates solutions in the left-hand side that are not compatible with the solutions on the right-hand side.

```
:alice foaf:givenName "Alice" ; foaf:familyName "Smith" .
:bob foaf:givenName "Bob" ; foaf:familyName "Jones" .
:carol foaf:givenName "Carol" ; foaf:familyName "Smith" .
```

```
SELECT DISTINCT ?s
WHERE { ?s ?p ?o . MINUS { ?s foaf:givenName "Bob" . } }
```

Results:

:carol
:alice

Relationship and differences between NOT EXISTS and MINUS

NOT EXISTS and **MINUS** represent two ways of thinking about negation

- one based on testing whether a pattern exists in the data, given the bindings already determined by the query pattern,
- one based on removing matches based on the evaluation of two patterns. In some cases they can produce different answers.

```
@prefix : <http://example/> .
:a :b :c .
```

```
SELECT * { ?s ?p ?o FILTER NOT EXISTS { ?x ?y ?z } }
```

No solutions because { ?x ?y ?z } matches given any ?s ?p ?o

```
SELECT * { ?s ?p ?o MINUS { ?x ?y ?z } }
```

There is no shared variable between the first part (?s ?p ?o) and the second (?x ?y ?z) so no bindings are eliminated.

Results:

```
:a :b :c
```

Property path

iri	
^elt	inverse path
elt / elt	sequence
elt | elt	alternative
elt*	repetition (0...n)
elt+	repetition (1...n)
elt?	option
!*iri* or !(iri_1| ...|iri_n)	negation
!^*iri* or !(^iri_1| ...|^iri_n)	negation of the inverse
!(iri_1| ...|iri_j|^iri_{j+1}| ...|^iri_n)	

Using property path to access lists

Recall that a list structure, written as

```
:france :flagColors (:blue :white :red) .
```

is an abbreviation for:

```
:france :flagColors [
    rdf:type rdf:List ;
    rdf:first :blue ;
    rdf:rest [
        rdf:type rdf:List ;
        rdf:first :white ;
        rdf:rest [
            rdf:type rdf:List ;
            rdf:first :red ;
            rdf:rest rdf:nil ]]]
```

Some queries over such structures can only be solved by using property path expressions.

Find all the colors in the french flag

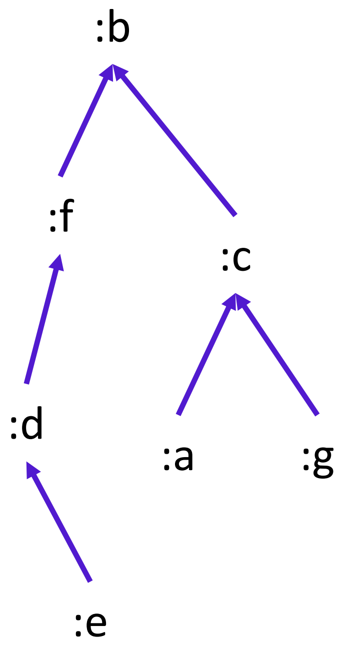
```
select ?c
where {:france :flagColors/rdf:rest*/rdf:first ?c }
```

Find the last color of the french flag

```
select ?c
where {:france :flagColors/rest* ?last.
          ?last rdf:rest rdf:nil. ?last rdf:first ?c }
```

Accessing Trees

Example: a part is decomposed into subparts, sub-subparts, etc. linked through a :partOf property.



Display all the parts that belong to :b

```
select ?p where {?p :partOf* :b. }
```

If part :a belongs to part :b, display its part number

```
select ?pn where {:a :partOf* :b. :a :partNo ?pn }
```

What are the subparts of :b that have more than 10 subparts (at any level)

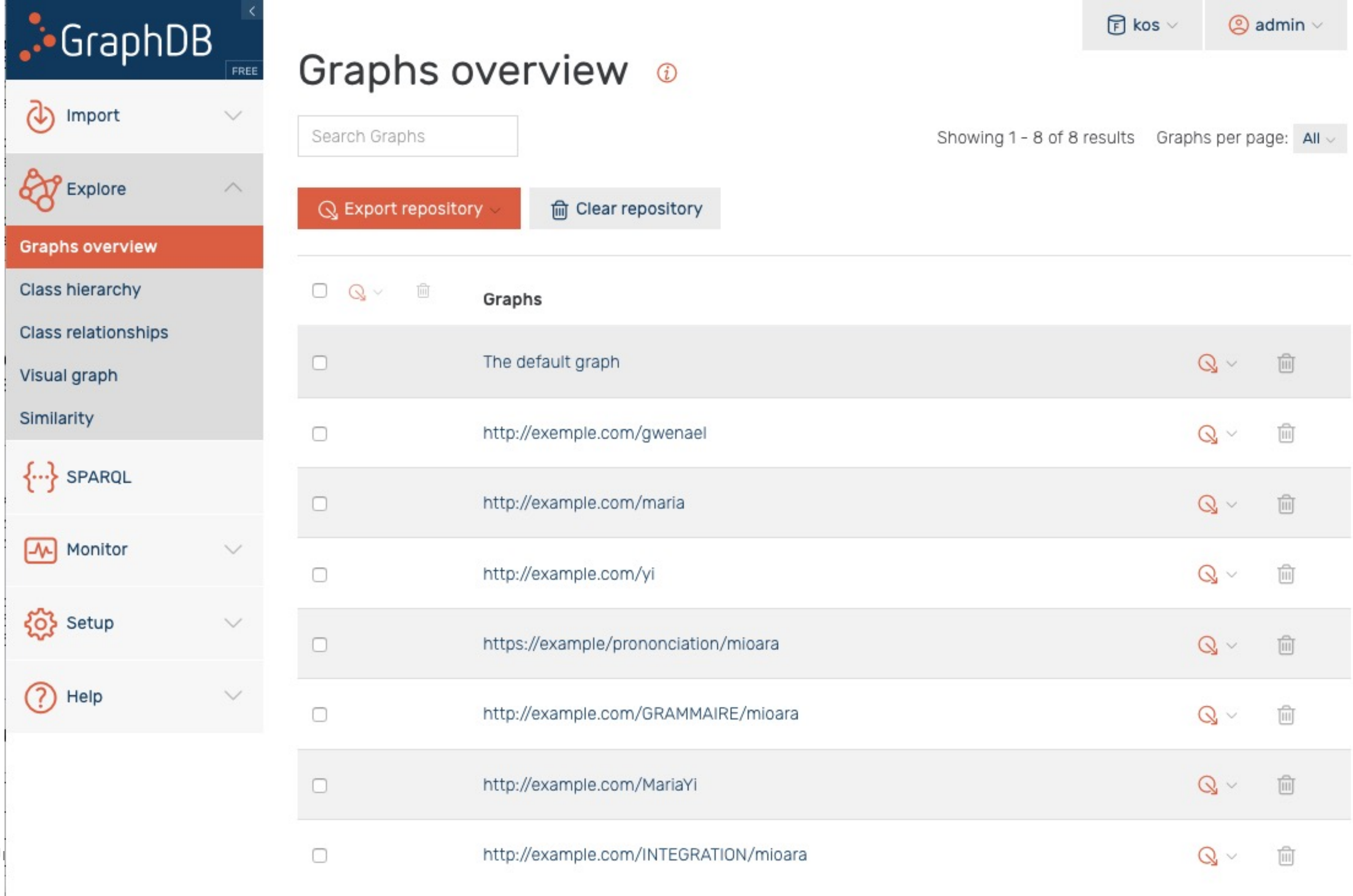
```
select ?p where {?p :partOf* :b.
filter count(select ?q where {?q partOf* ?p}) > 10 }
```

RDF Datasets

- Many RDF data stores hold multiple RDF graphs
- A SPARQL query is executed against an RDF Dataset
- An RDF Dataset comprises
  - the default graph, which does not have a name
  - zero or more named graphs identified by IRIs.
- A SPARQL query can match different parts of the query pattern against different graphs
  - The graph that is used for matching a basic graph pattern is the active graph.
  - The GRAPH keyword is used to make the active graph one of all of the named graphs in the dataset for part of the query.

In SPARQL

```
PREFIX ...
SELECT ...
FROM <...>         # add this graph to the default graph of the query dataset
FROM NAMED <...> # add this graph as a named graph of the query dataset
WHERE { ... }
```


GraphDB
FREE
kos
admin
Graphs overview
Search Graphs
Showing 1 - 8 of 8 results
Graphs per page: All
Export repository
Clear repository
Import
Explore
Graphs overview
Class hierarchy
Class relationships
Visual graph
Similarity
SPARQL
Monitor
Setup
Help
Graphs
The default graph
http://exemple.com/gwenael
http://example.com/maria
http://example.com/yi
https://example/prononciation/mioara
http://example.com/GRAMMAIRE/mioara
http://example.com/MariaYi
http://example.com/INTEGRATION/mioara

```
select (count(*) as ?nbTriples)
from  <http://exemple.com/gwenael>
where { # query the default graph
    {?s ?p ?o .}
}
```

```
Results
nbTriples
4562
```

```
select (count(*) as ?nbTriples)
from  <http://exemple.com/gwenael>
from  <http://example.com/maria>
where {  # query the default graph
    {?s ?p ?o .}
}
```

Results

```
nbTriples
7066
```

```
select (count(*) as ?nbTriples)
from named <http://exemple.com/gwenael>
where {  # query over the default graph
    {?s ?p ?o .}
}
```

Results

nbTriples

0

```
select (count(*) as ?nbTriples)
from named <http://exemple.com/gwenael>
where {
    graph <http://exemple.com/gwenael> {?s ?p ?o .}
}
```

Results

nbTriples
4562

```
select (count(*) as ?nbTriples)
from named <http://exemple.com/gwenael>
from  <http://example.com/maria>
where {
    graph <http://exemple.com/gwenael> {?s ?p ?o .}
}
```

Results

nbTriples

4562

The default default graph is the merge of the graphs

```
select (count(*) as ?nbTriples)
where {
    ?s ?p ?o .
}
```

Results

```
nbTriples
18595
```

Blank nodes in graphs and results

```
ex:MITPress
  ex:published ex:bk1 ;
  ex:published _:2 .
```

- Blank nodes are local
- They have no URI
- They cannot be "exported" to the answer
- The answer mapping must "invent" blank nodes

```
select ?pub where {ex:MITPress ex:published ?pub}
```

Infinitely many possible answers ?

?pub
ex:every
_:cx323322

?pub
ex:every
_:abc

?pub
ex:every
_:u123

Scoping Graph – to avoid infinite answers

- Since SPARQL treats blank node identifiers in a results format document as scoped to the document, they cannot be understood as identifying nodes in the active graph of the dataset.

- If DS is the dataset of a query, pattern solutions are therefore understood to be not from the active graph of DS itself, but from an RDF graph, called the *scoping graph*, which is graph-equivalent to the active graph of DS but shares no blank nodes with DS or with BGP.

- The same scoping graph is used for all solutions to a single query.

SPARQL Algebra

- to define the semantics of SPARQL
- to implement SPARQL query engines

Operations on solutions produced by **Basic graph pattern matching**

SPARQL Algebra

Graph Pattern	Solution Modifier	Property Path
Join LeftJoin Filter Union Graph Extend Minus Group Aggregation AggregateJoin	ToList OrderBy Project Distinct Reduced Slice ToMultiSet	PredicatePath InversePath SequencePath AlernativePath ZeroOrMorePath OneOrMorePath ZeroOrOnePath NegatedPropertySet

Operations on multisets of solutions

$\{\{x \rightarrow 3, y \rightarrow :aaa\} * 2, \{x \rightarrow 7, y \rightarrow bbb, z \rightarrow ccc\} * 3\}$

Join(Ω1, Ω2) =

{ merge(μ1, μ2) | μ1 in Ω1 and μ2 in Ω2, and μ1 and μ2 are compatible }

μ_1 and μ_2 are compatible if, for every variable v in dom(μ_1) and in dom(μ_2), $\mu_1(v) = \mu_2(v)$.

Card(μ in Join(Ω1, Ω2)) = the number of ways to get μ from elements of Ω1 and Ω2

LeftJoin(Ω1, Ω2, expr) =

Filter(expr, Join(Ω1, Ω2)) ∪ Diff(Ω1, Ω2, expr))

From SPARQL to SPARQL Algebra

1. Extend syntactic forms for IRIs, literals and triple patterns
2. Translate property path expressions
3. Convert some property path patterns into triples
4. Gather the group FILTERs
5. Translate the basic graph patterns
6. Translate the remaining graph patterns in the group
7. Add the filters
8. Simplify the algebraic expression

Translate Property Path Expressions

SPARQL Syntax	Algebra
iri	link(iri)
^path	inv(path)
$!(iri_1\|...\|iri_n)$	NPS($\{iri_1 \ldots iri_n\}$) (Negated Property Set)
$!(\hat{}iri_1\|...\|\hat{}iri_n)$	inv(NPS($\{iri_1 \ldots iri_n\}$))
$!(iri_1\|...\|iri_i\|\hat{}iri_{i+1}\|...\|\hat{}iri_n)$	alt(NPS($\{iri_1 \ldots iri_i\}$), inv(NPS($\{iri_{i+1} \ldots iri_n\}$))
path1 / path2	seq(path1, path2)
path1 | path2	alt(path1, path2)
path*	ZeroOrMorePath(path)
path+	OneOrMorePath(path)
path ?	ZeroOrOnePath(path)

Convert some property path patterns into triples

subject, property path expression, object
⇒ triple patterns
⇒ or general algebra operation for path evaluation.

Algebra	SPARQL
X link(iri) Y	X iri Y
X inv(iri) Y	Y iri X
X seq(P, Q) Y	X P $?V_{new}$. $?V_{new}$ Q Y
X P Y	Path(X, P, Y)

?s :p/:q ?o

?s :p? v . ?v :q ?o

?s :p* ?o

Path(?s, ZeroOrMorePath(link(:p)), ?o)

:list rdf :rest*/rdf :first ?member

Path(:list, ZeroOrMorePath(link(rdf :rest)), ?v) . ?v rdf :first ?member

- After translating property paths, any adjacent triple patterns are collected together to form a basic graph pattern

BGP(triples).

Translating General Graph Patterns (simplified)

basic graph pattern:

Tr(P) = BGP(Tr(P)))

union:

Tr(P1 UNION P2) = Union(t(P1), t(P2))

option:

Tr(P1 OPTIONAL{P2}) = LeftJoin(Tr(P1), Tr(P2), true)

Tr(P1 OPTIONAL{P2 FILTER (F)}) = LeftJoin(Tr(P1), Tr(P2), F)

filter:

Tr({P1 FILTER)(E)}) = Filter(E, Tr(P1))

others:

Tr({P1 P2}) = Join(Tr(P1), Tr(P2))

Examples

{?s ?p ?o }

BGP(?s ?p ?o)

{?s :p1?v1; :p2 ?v2 }

BGP(?s :p1 ?v1 . ?s :p2 ?v2)

{?s :p1 ?v1 OPTIONAL {?s :p2 ?v2 } OPTIONAL {?s :p3 ?v3 } }

```
LeftJoin(
   LeftJoin(BGP( ?s :p1 ?v1), BGP( ?s :p2 ?v2), true) ,
   BGP( ?s :p3 ?v3),
   true)
```