SPARQL

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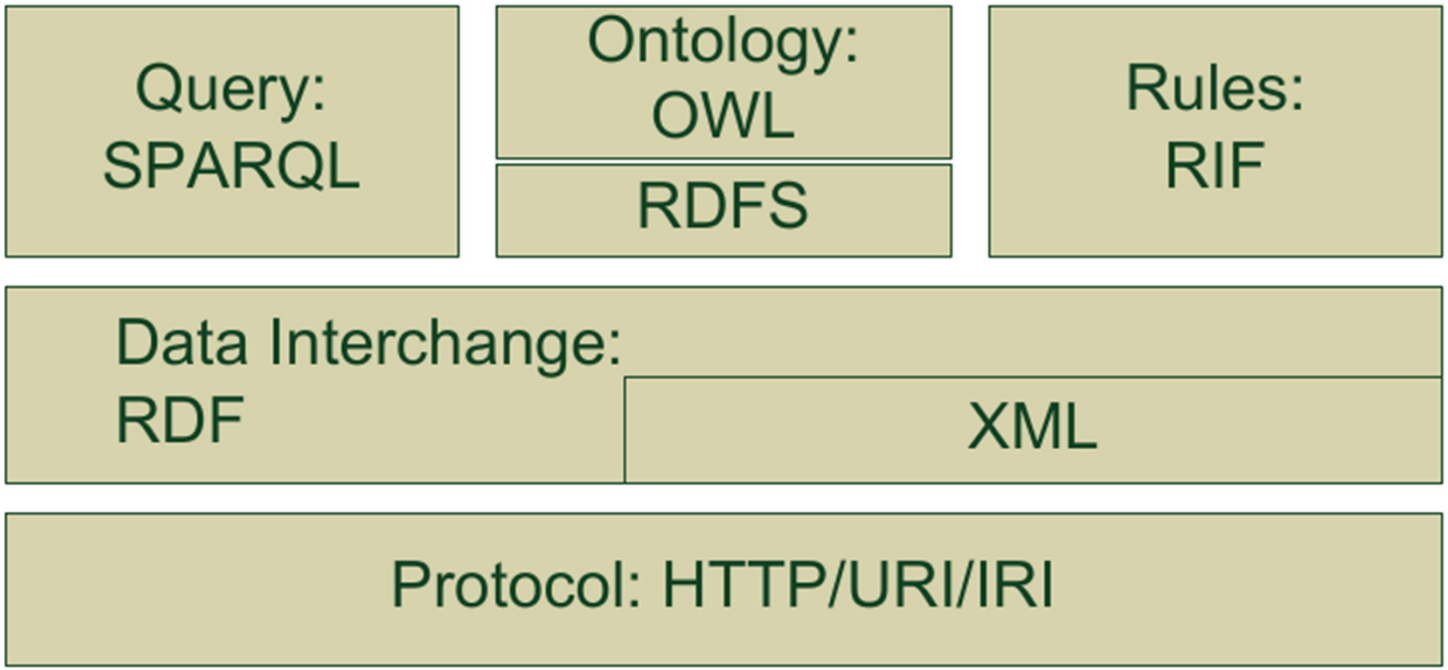
Semantic Web

Semantic Web Language Layer Cake



Existing standards

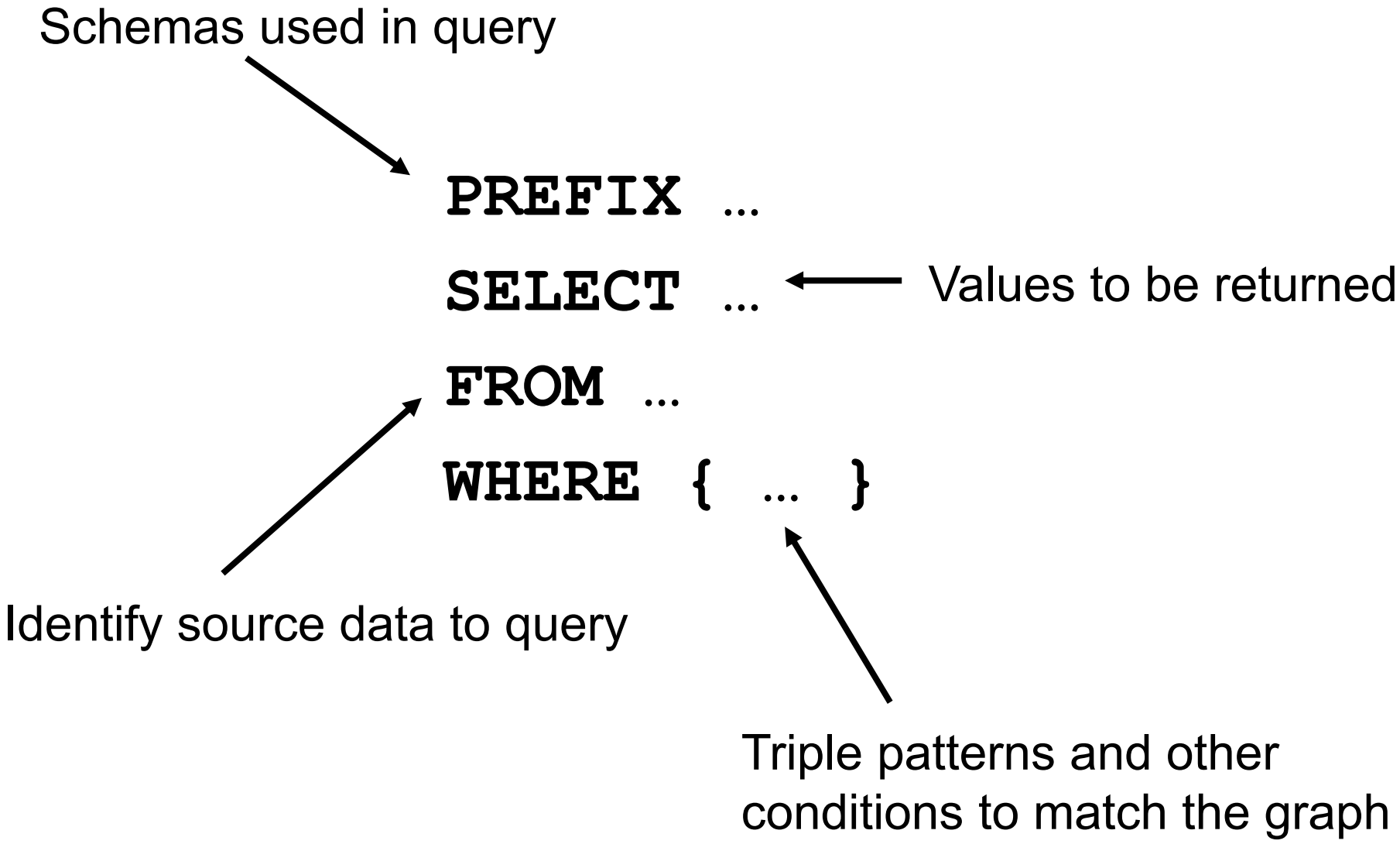
SPARQL

- **S**PARQL **P**rotocol **a**nd **R**DF **Q**uery **L**anguage

- W3C Recommendation 15 January 2008
  - http://www.w3.org/TR/rdf-sparql-query/

- Standard query language for RDF
  - Native RDF knowledge bases
  - Knowledge bases viewed as RDF via middleware
- Language for querying for graph patterns
  - Includes unions, conjunctions and optional patterns
  - No support for inserts or updates
- Supports extensible testing for values and constraints

SPARQL Query



SPARQL Query types

- **SELECT**
  - returns the set of variables bound in a query pattern match
- **CONSTRUCT**
  - returns an RDF graph constructed by substituting variables in a set of triple templates
- **DESCRIBE**
  - returns an RDF graph that describes the resources found
- **ASK**
  - returns whether a query pattern matches any triples or not True / False query

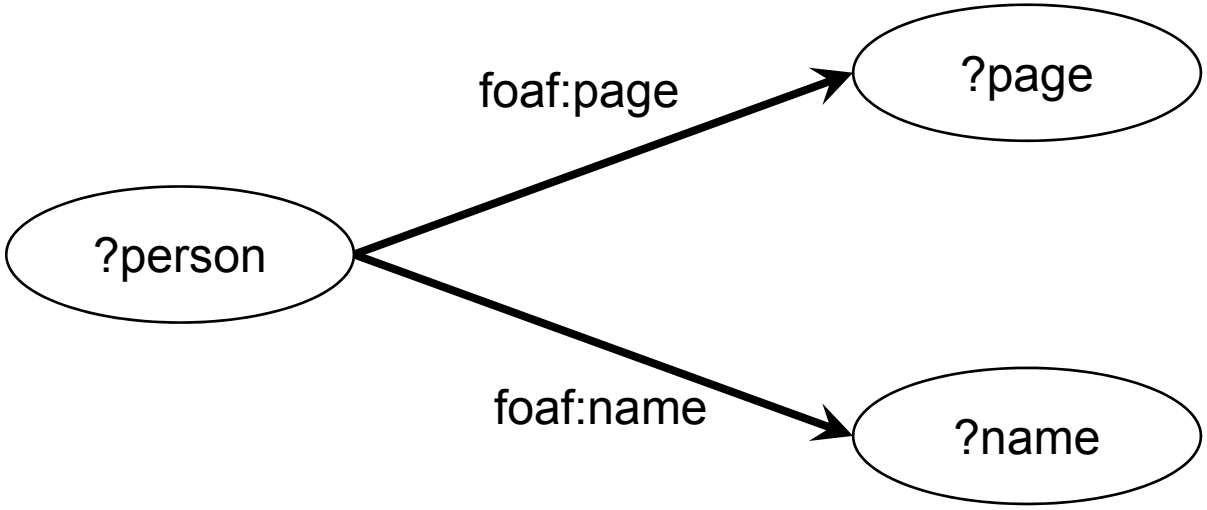
Basic SPARQL patterns

- Triple Pattern
  - Similar to an RDF Triple
    - `subject, predicate, object`
  - Any component can be a query variable
  - Any combination of variables in the query is allowed

- Matching patterns in the **WHERE** clause
  - Matching conjunction of Triple Patterns
  - Matching a triple pattern to a graph
    - Finding bindings between variables and RDF Terms
  - Underneath use of reasoners
    - Infering triples originally not present in the knowledge base

Simple SPQRQL Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?page
WHERE {
  ?person foaf:page ?page .
  ?person foaf:name ?name
}
```



Query example

Data

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
 _:a foaf:name "Steffen Staab" .
 _:a foaf:homepage <http://www.uni-koblenz.de/~staab> .
 _:b foaf:name "Maciej Janik" .
 _:b foaf:homepage <http://www.uni-koblenz.de/~janik> .
```

Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?page
WHERE {
 ?person foaf:homepage ?page .
 ?person foaf:name ?name
}
```

Query Result

name	page
"Steffen Staab"	<http://www.uni-koblenz.de/~staab>
"Maciej Janik"	<http://www.uni-koblenz.de/~janik>

Querying for blank nodes

Data

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
 _:a foaf:name "Steffen Staab" .
 _:a foaf:homepage <http://www.uni-koblenz.de/~staab> .
 _:b foaf:name "Maciej Janik" .
 _:b foaf:homepage <http://www.uni-koblenz.de/~janik> .
```

Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?person ?name ?page
WHERE {
 ?person foaf:homepage ?page .
 ?person foaf:name ?name
}
```

Query Result

person	name	homepage
_:c	"Steffen Staab"	<http://www.uni-koblenz.de/~staab>
_:d	"Maciej Janik"	<http://www.uni-koblenz.de/~janik>

Filters

- **FILTER**
  - Further constrain graph patterns
  - Applies to the **whole group** of triple patterns

- **FILTER** clause
  - Support for AND and OR logic operators
  - Extensive applications for testing literals
  - Support for numerical operations
  - Support for math equality operators for literals
    - Less than …equal … greater than
  - Use of regular expressions
  - Support for datatypes defined in XSL
    - e.g. comparison of dates, time
  - Possible comparison of resources
    - Equal or not equal
  - Even possible user extensions

Filter – Value Constraints

Data

```
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix ex: <http://example.org/book/> .
@prefix ns: <http://example.org/ns#> .
ex:book1 dc:title "SPARQL Tutorial" .
ex:book1 ns:price 42 .
ex:book2 dc:title "The Semantic Web" .
ex:book2 ns:price 23 .
```

Query

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
PREFIX ns: <http://example.org/ns#>
SELECT ?title ?price
WHERE { ?x ns:price ?price .
        FILTER ?price < 30 .
        ?x dc:title ?title }
```

Query Result

title	price
"The Semantic Web"	23

Scope of filters

- Filters are applied to the whole group of patterns where it appears

```
{ ?x foaf:name ?name .
  ?x foaf:homepage ?page .
  FILTER regex(?name, "Steffen")  }
```

```
{ ?x foaf:name ?name .
  FILTER regex(?name, "Steffen") .
  ?x foaf:homepage ?page  }
```

```
{ FILTER regex(?name, "Steffen") .
  ?x foaf:name ?name .
  ?x foaf:homepage ?page   }
```

- These patterns are equivalent – have the same solution.

Filter – regular expression

Data

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
 _:a foaf:name "Steffen Staab" .
 _:a foaf:homepage <http://www.uni-koblenz.de/~staab> .
 _:b foaf:name "Maciej Janik" .
 _:b foaf:homepage <http://www.uni-koblenz.de/~janik> .
```

Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?page
WHERE {
 ?person foaf:homepage ?page .
 ?person foaf:name ?name .
 FILTER regex(?name, "Steffen")
}
```

Query Result

name	page
"Steffen Staab"	<http://www.uni-koblenz.de/~staab>

Filter – regular expression

Data

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
 _:a foaf:name "Steffen Staab" .
 _:a foaf:homepage <http://www.uni-koblenz.de/~staab> .
 _:b foaf:name "Maciej Janik" .
 _:b foaf:homepage <http://www.uni-koblenz.de/~janik> .
```

Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?page
WHERE {
 ?person foaf:homepage ?page .
 ?person foaf:name ?name .
 FILTER regex(?name, "i", "janik")
}
```

Case insensitive

Query Result

name	page
"Maciej Janik"	<http://www.uni-koblenz.de/~janik>

Optional patterns

- **OPTIONAL**
  - Include optional triple patterns to the match
  - Optional is a pattern itself – can include further constraints

```
SELECT
WHERE {
    …
    OPTIONAL { … }
}
```

- OPTIONAL is left-associative

  `pattern OPTIONAL { pattern } OPTIONAL { pattern }`

  is the same as

  `{ pattern OPTIONAL { pattern } } OPTIONAL { pattern }`

Query example

Data

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
 _:a foaf:name "Steffen Staab" .
 _:a foaf:homepage <http://www.uni-koblenz.de/~staab> .
 _:b foaf:name "Maciej Janik" .
 _:b foaf:mbox <janik@uni-koblenz.de> .
```

Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?page
WHERE {
   ?person foaf:name ?name .
   ?person foaf:homepage ?page
}
```

Query Result

name	page
"Steffen Staab"	<http://www.uni-koblenz.de/~staab>

Query example - OPTIONAL

Data

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
 _:a foaf:name "Steffen Staab" .
 _:a foaf:homepage <http://www.uni-koblenz.de/~staab> .
 _:b foaf:name "Maciej Janik" .
 _:b foaf:mbox <janik@uni-koblenz.de> .
```

Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?page
WHERE {
  ?person foaf:name ?name .
  OPTIONAL (?person foaf:homepage ?page)
}
```

Query Result

name	page
"Steffen Staab"	<http://www.uni-koblenz.de/~staab>
"Maciej Janik"	

Union of graph patterns

- **UNION**
  - Combining alternative graph patterns
  - If more than one of the alternatives matches, all the possible pattern solutions are included in result

```
SELECT
WHERE {
      { pattern }
      UNION
      { pattern }
}
```

Union of graph patterns

Data

```
@prefix dc10: <http://purl.org/dc/elements/1.0/> .
@prefix dc11: <http://purl.org/dc/elements/1.1/> .
:book1 dc10:title "SPARQL Tutorial" .
:book1 dc10:creator “Alice” .
:book2 dc11:title "The Semantic Web" .
:book2 dc11:creator “Robert .
```

Query

```
PREFIX dc10: <http://purl.org/dc/elements/1.0/>
PREFIX dc11: <http://purl.org/dc/elements/1.1/>
SELECT ?title
WHERE { { ?x dc10:title ?title }
        UNION
        { ?x dc11:title ?title } }
```

Query Result

title
“SPARQL Tutorial”
"The Semantic Web"

Modification to the result set

Result of SPARQL query can be further modified

- ORDER BY
  - Sort results alphabetically / numerically by specific variable
- LIMIT
  - Limit number of returned results (only top n results)
- OFFSET
  - Skip n top results, and return the rest

These expressions can be combined in one query

Sequencing and limiting results

Results 11 to 30 sorted by name

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?page
WHERE {
 ?person foaf:homepage ?page .
 ?person foaf:name ?name
}
ORDERBY ?name
LIMIT 20
OFFSET 10
```

Bound variables

- One of the FILTER expressions
- Supports testing if a variable in a query can be bound to an instance in the knowledge base
- Mostly used for negation as failure

```
PREFIX foaf: < http://xmlns.com/foaf/0.1/>
SELECT ?name
WHERE {
   ?person foaf:name ?name .
   OPTIONAL { ?person foaf:knows ?x . }
   FILTER ( ! bound(?x))
}
```

Tricky negation

Find people who do not know Steffen

```
PREFIX foaf: < http://xmlns.com/foaf/0.1/>
SELECT ?name
WHERE {
   ?person foaf:name ?name .
   ?person foaf:knows ?x .
   FILTER ( ?x != "Steffen" )
}
```

… we know that …

"Maciej" foaf:knows "Steffen"

"Maciej" foaf:knows "Sergej"

… so "Maciej" is still a valid answer, and we do not want it.

Negation with bound

Find people who do not know Steffen

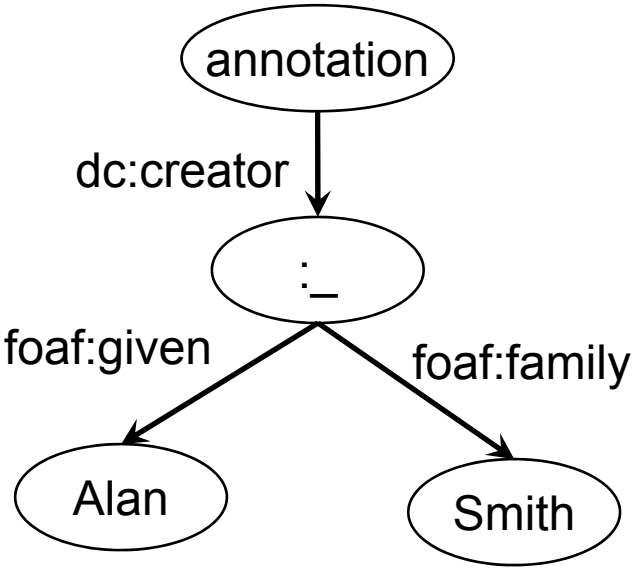
now the correct way using bound expression and optional graph pattern

```
PREFIX foaf: < http://xmlns.com/foaf/0.1/>
SELECT ?name
WHERE {
   ?person foaf:name ?name .
   OPTIONAL { ?person foaf:knows ?x .
              FILTER ( ?x = “Steffen” ) }
   FILTER ( ! bound(?x) ) }
}
```

Other SPARQL filter expressions

- **isBlank**
  - Testing if bounded variable is a blank node

```
SELECT ?given ?family
WHERE { ?annot  dc:creator ?c .
          OPTIONAL {
            ?c foaf:given ?given .
            ?c foaf:family ?family }.
          FILTER isBlank(?c) }
```



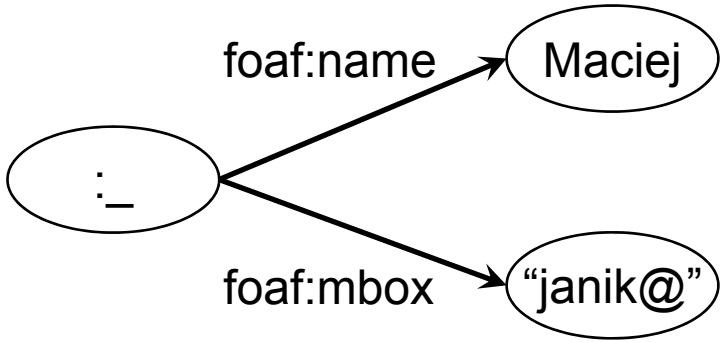
- **lang**
  - Accessing the language of a literal

```
SELECT ?name ?mbox
WHERE { ?x foaf:name ?name .
        ?x foaf:mbox ?mbox .
        FILTER ( lang(?name) = "DE" ) }
```

Other SPARQL filter expressions

- **isLiteral**
  - Testing if bounded variable is a literal (not a resource)

```
SELECT ?name ?mbox
WHERE { ?x foaf:name ?name .
        ?x foaf:mbox ?mbox .
        FILTER isLiteral(?mbox) }
```



- **str**
  - Converting resource URI to string for regular expression matching

```
SELECT ?name ?mbox
WHERE { ?x foaf:name ?name .
        ?x foaf:mbox ?mbox .
        FILTER regex(str(?mbox), "@uni-koblenz.de") }
```

Equal terms and same terms

- Check if two terms are equal or if they describe the same entity
  - Same entity can have even different URIs, but conneced with owl:sameAs

```
term1 = term2
```

or

```
sameTerm(term1, term2)
```

Returns true, if

- terms are of the same type (URI, literal, blank node)
- two terms represent URIs are equivalent
- two terms represent literals are equivalent
- two terms are bound by the same blank node

Equal terms

- Find people who have the same email address, but use different names

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
_:a foaf:name "Alice".
_:a foaf:mbox <mailto:alice@work.example> .
_:b foaf:name "Ms A.“ .
_:b foaf:mbox <mailto:alice@work.example> .
```

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name1 ?name2
WHERE {
  ?x foaf:name ?name1 .
  ?x foaf:mbox ?mbox1 .
  ?y foaf:name ?name2 .
  ?y foaf:mbox ?mbox2 .
  FILTER ( sameTerm(mbox1, ?mbox2) && ?name1 != ?name2) }
```

User-defined functions

- FILTER enables using user-defined expressions

```
PREFIX aGeo: <http://example.org/geo#>
SELECT ?neighbor WHERE {
  ?a aGeo:placeName "Koblenz" .
  ?a aGeo:location ?axLoc .
  ?a aGeo:location ?ayLoc .
  ?b aGeo:placeName ?neighbor .
  ?b aGeo:location ?bxLoc .
  ?b aGeo:location ?byLoc .
  FILTER
   ( aGeo:distance(?axLoc, ?ayLoc, ?bxLoc, ?byLoc) < 5 )
}
```

Definition of user function

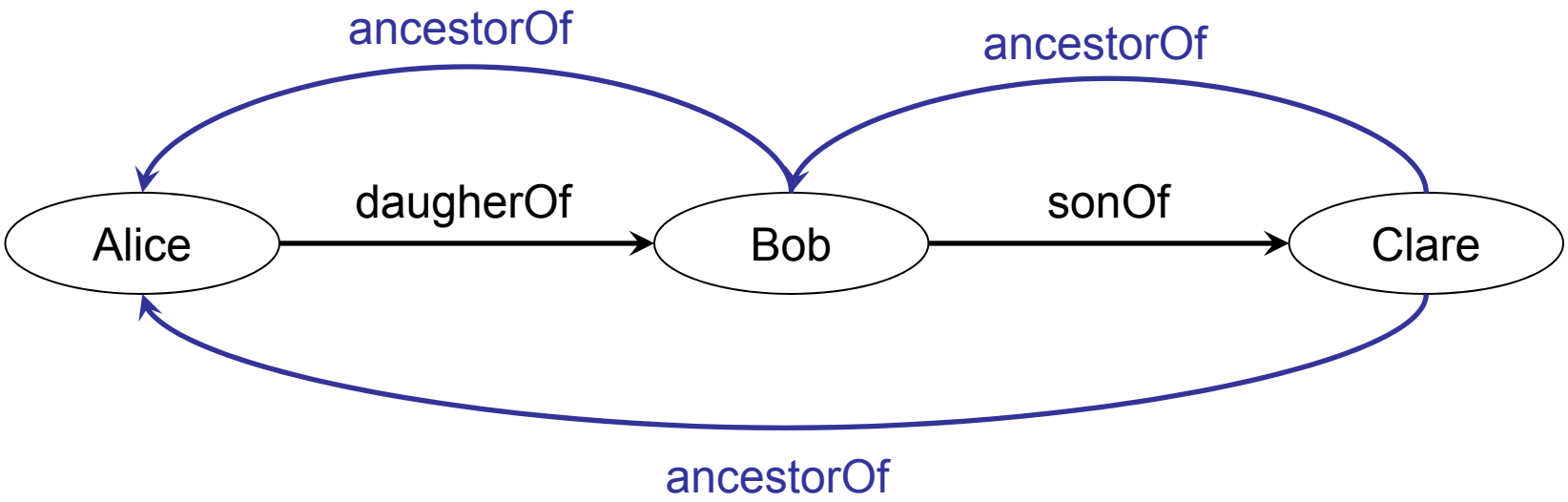
Geometric distance between two points described by (x, y) coordinates

```
xsd:double   aGeo:distance (numeric x1, numeric y1,
                            numeric x2, numeric y2)
```

Querying for inferred knowledge

- SPARQL do not have specific constructs for accessing inferred knowledge
  - Underlying knowledge base is responsible for supporting inference, e.g.
    - Class hierarchy
    - Property hierarchy
    - Transitive or symmetric properties
    - OWL restrictions
    - Defining classes by unions and/or intersections
- Different knowledge bases can offer different level of support
  - Same knowledge in different knowledge bases may return different results for the same query, depending on **supported entailment**

Query example



ancestorOf = owl:transitiveProperty + union (inverse(daugherOf), inverse(sonOf))

Find ancestors of Alice

Query

```
SELECT ?x
WHERE ?x ancestorOf "Alice"
```

Result

"Clare"
"Bob"

CONSTRUCT queries

- Special type of query to construct a new RDF graph from the existing knowledge base

```
PREFIX ……
CONSTRUCT
{
    … graph pattern …
    … definition of triples …
}
WHERE
{
    constraint triple patterns, filters, etc
}
```

Constructing graphs

▪**Data:**

```
@prefix foaf:
<http://xmlns.com/foaf/0.1/> .
_:a foaf:givenname "Alice" .
_:a foaf:family_name "Hacker" .
_:b foaf:firstname "Bob" .
_:b foaf:surname "Hacker" .
```

▪**Query:**

```
PREFIX foaf:
<http://xmlns.com/foaf/0.1/>
PREFIX vcard:
<http://www.w3.org/2001/vcard-
rdf/3.0#>
CONSTRUCT
{
?x vcard:N _:v .
_:v vcard:givenName ?gname .
_:v vcard:familyName ?fname
}
WHERE
{
  { ?x foaf:firstname ?gname }
    UNION
  { ?x foaf:givenname ?gname } .
  { ?x foaf:surname ?fname }
    UNION
  { ?x foaf:family_name ?fname }
}
```

▪**Result:**

```
@prefix vcard:
<http://www.w3.org/2001/vcard-rdf/3.0#>
_:v1 vcard:N          _:x .
 _:x vcard:givenName  "Alice" .
 _:x vcard:familyName "Hacker" .
 _:v2 vcard:N         _:z .
 _:z vcard:givenName  "Bob" .
_:z vcard:familyName "Hacker" .
```

ASK queries

- True / false queries – checks if given set of triple patterns have at least one match in knowledge base
- Does not include ORDER BY, LIMIT or OFFSET

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
_:a foaf:name "Alice" .
_:a foaf:homepage <http://work.example.org/alice/> .
_:b foaf:name "Bob" .
_:b foaf:mbox <mailto:bob@work.example>
```

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
ASK { ?x foaf:name "Alice" .
      ?x foaf:mbox ?y }
```

Answer: NO

DESCRIBE queries

- Returns a graph that includes description of specific resources
- Results of DESCRIBE query reveal metainformation not returned by standard SELECT query
  - Type of bounded resources
  - Types of relationships used in query pattern
- Exact description of resources is determined by the query service
  - No common standard of description
  - Can even include information about related resources

DESCRIBE query example

```
PREFIX ent: <http://org.example.com/employees#>
DESCRIBE ?x
WHERE { ?x ent:employeeId "1234" }
```

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix vcard: <http://www.w3.org/2001/vcard-rdf/3.0> .
@prefix exOrg: <http://org.example.com/employees#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix owl: <http://www.w3.org/2002/07/owl#>

_:a     exOrg:employeeId "1234" ;
        foaf:mbox_sha1sum "ABCD1234" ;
        vcard:N
            [ vcard:Family "Smith" ;
              vcard:Given "John" ] .

foaf:mbox_sha1sum rdf:type owl:InverseFunctionalProperty
```

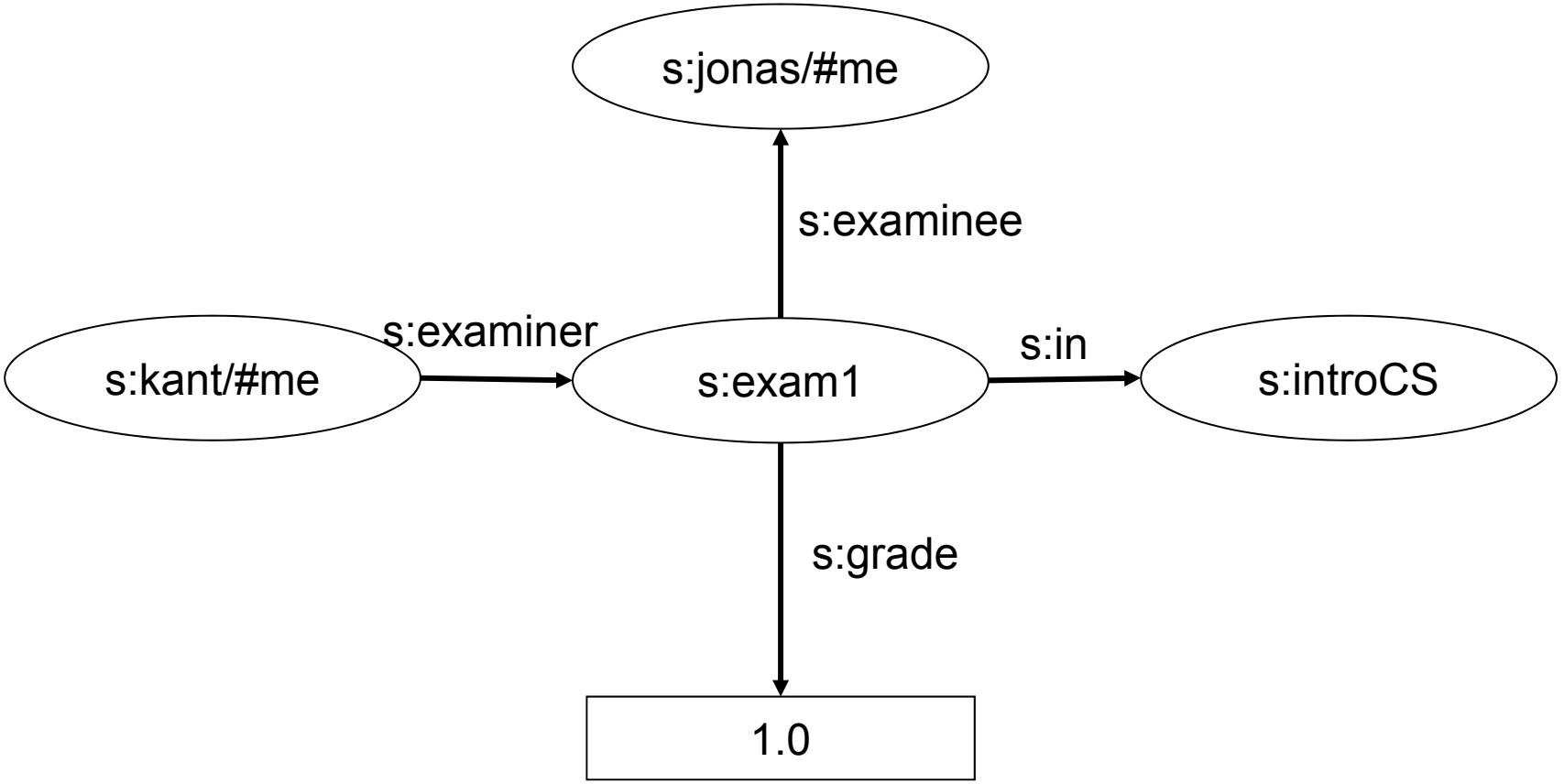
Named Graphs

- RDF data stores may hold multiple RDF graphs:
  - record information about each graph
  - queries that involve information from more than one graph
  - default graph (does not have a name)
  - multiple named graphs (identified by URI reference)
  - direct implementation for reification

- Accessing named graphs
  - FROM
    - access knowledge in default graph
  - FROM NAMED
    - access information from specific named graph

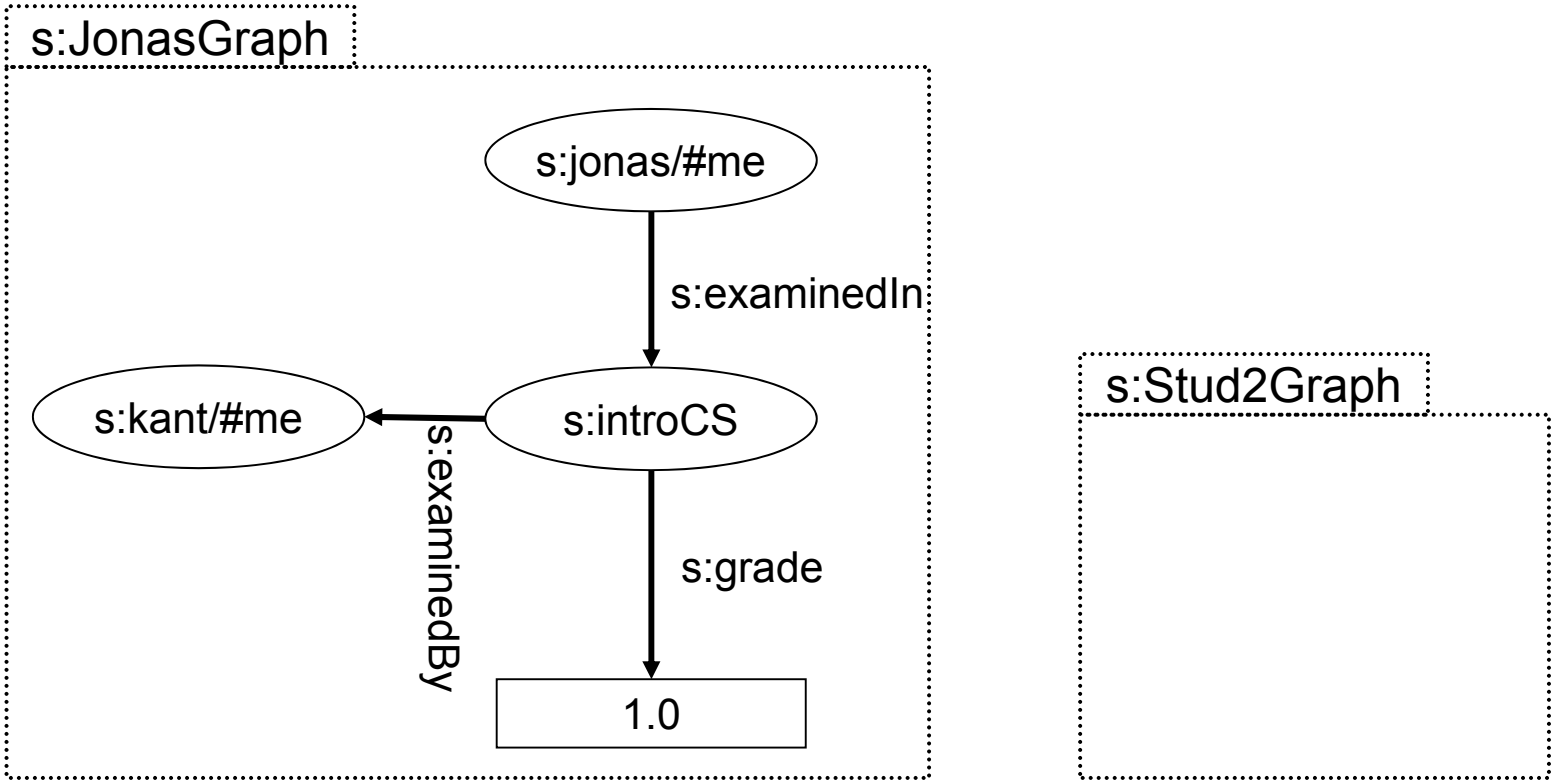
Ad hoc-Reification (direct)

„Kant“ examined „Jonas“ in „Introduction to CS“ and gave him grade „1.0“



Named Graph as reification

„Kant“ examined „Jonas“ in „Introduction to CS“ and gave him grade „1.0“



Named graph examples

```
# Default graph (http://example.org/friends)
@prefix dc: <http://purl.org/dc/elements/1.1/> .
<http://example.org/bob> dc:publisher "Bob" .
<http://example.org/alice> dc:publisher "Alice" .
# Graph: http://example.org/bob
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
_:a foaf:name "Bob" .
_:a foaf:mbox <mailto:bob@oldcorp.example.org> .
# Graph: http://example.org/alice
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example.org> .

SELECT ...
FROM NAMED <http://example.org/alice>
FROM NAMED <http://example.org/bob>
...
```

Relationships between named graphs

```
# Default graph
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
_:y foaf:name "Alice" .
_:y foaf:mbox <mailto:alice@work.example.org> .
_:y foaf:mbox <mailto:alice@oldcorp.org> .
```

```
# Graph: http://example.org/alice
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example.org> .
```

```
# Graph: http://example.org/alice_prev
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@oldcorp.org> .
```

Accessing named graphs

```
# Graph: http://example.org/alice
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example.org> .
# Graph: http://example.org/alice_prev
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@oldcorp.org> .
```

```
SELECT ?src ?mbox
WHERE {
  GRAPH ?src
  { ?x foaf:name "Alice" .
    ?x foaf:mbox ?mbox
  }
}
```

Result:

src	mbox
http://example.org/alice	mailto:alice@work.example.org
http://example.org/alice_prev	mailto:alice@oldcorp.org

Restricting access by graph name

```
# Graph: http://example.org/alice
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@work.example.org> .
# Graph: http://example.org/alice_prev
_:a foaf:name "Alice" .
_:a foaf:mbox <mailto:alice@oldcorp.org> .
```

```
PREFIX ex: <http://example.org/>
SELECT ?mbox
WHERE {
  GRAPH ex:alice
  { ?x foaf:mbox ?mbox }
}
```

Result:

mbox
mailto:alice@work.example.org