SPARQL

Petr Křemen

petr.kremen@fel.cvut.cz

October 7, 2020

Outline

1. SPARQL
   - SPARQL Query Language Basics
   - SPARQL Update (Graph Update Operations)

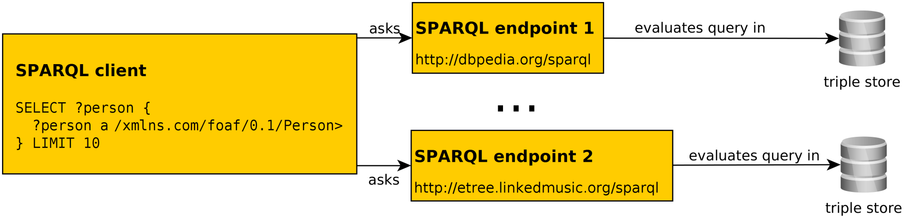
SPARQL

A simple SPARQL Query

```
SELECT ?person {
  ?person a <http://xmlns.com/foaf/0.1/Person> .
} LIMIT 10
```

To be queried over RDF data inside a **SPARQL endpoint**, e.g. `http://dbpedia.org/sparql`

SPARQL idea



SPARQL client
SELECT ?person {
?person a /xmlns.com/foaf/0.1/Person>
} LIMIT 10
asks
asks
SPARQL endpoint 1
http://dbpedia.org/sparql
...
SPARQL endpoint 2
http://etree.linkedmusic.org/sparql
evaluates query in
evaluates query in
triple store
triple store

SPARQL Factsheet

- SPARQL 1.1 – 12 W3C Recommendations on 21 March 2013, covering
  - a query language (SPARQL 1.1 Query Language) [**Harris:13:SQL**]

SPARQL Factsheet

- SPARQL 1.1 – 12 W3C Recommendations on 21 March 2013, covering
  - a query language (SPARQL 1.1 Query Language) [**Harris:13:SQL**]
  - an update language (SPARQL 1.1. Update language)

SPARQL Factsheet

- SPARQL 1.1 – 12 W3C Recommendations on 21 March 2013, covering
  - a query language (SPARQL 1.1 Query Language) [**Harris:13:SQL**]
  - an update language (SPARQL 1.1. Update language)
  - SPARQL services (protocol over HTTP, graph management HTTP protocol),

SPARQL Factsheet

- SPARQL 1.1 – 12 W3C Recommendations on 21 March 2013, covering
  - a query language (SPARQL 1.1 Query Language) [**Harris:13:SQL**]
  - an update language (SPARQL 1.1. Update language)
  - SPARQL services (protocol over HTTP, graph management HTTP protocol),
  - an extension for executing distributed queries over more SPARQL endpoints [**Aranda:13:SFQ**]

SPARQL Factsheet

- SPARQL 1.1 – 12 W3C Recommendations on 21 March 2013, covering
  - a query language (SPARQL 1.1 Query Language) [**Harris:13:SQL**]
  - an update language (SPARQL 1.1. Update language)
  - SPARQL services (protocol over HTTP, graph management HTTP protocol),
  - an extension for executing distributed queries over more SPARQL endpoints [**Aranda:13:SFQ**]
  - JSON, CSV, TSV, XML query result formats [**Seaborne:13:SQR**]

SPARQL Factsheet

- SPARQL 1.1 – 12 W3C Recommendations on 21 March 2013, covering
  - a query language (SPARQL 1.1 Query Language) [**Harris:13:SQL**]
  - an update language (SPARQL 1.1. Update language)
  - SPARQL services (protocol over HTTP, graph management HTTP protocol),
  - an extension for executing distributed queries over more SPARQL endpoints [**Aranda:13:SFQ**]
  - JSON, CSV, TSV, XML query result formats [**Seaborne:13:SQR**]
  - definition of entailment regimes for RDF extensions (e.g. OWL, more in lecture 10) [**Ogbuji:13:SER**].

SPARQL for RDF is like SQL for RDBMS

'Get projects having male administrators starting on the letter N'

```
SELECT e.surname AS es,
       p.name AS pn
FROM employee e, project p
WHERE e.gender = 'male'
      AND p.administratorId = e.id
      AND e.surname LIKE 'N\%';
```

```
PREFIX : <http://example.org/>
SELECT ?sn, (?projname AS ?pn)
WHERE {
  ?e a :Employee .
  ?e :surname ?sn .
  ?e :gender 'male'.
  ?p a :Project .
  ?p :name ?pn .
  ?p :administrator ? e.
  FILTER (strstarts(?sn,'N'))
}
```

However, SPARQL is less powerful comparing to SQL in terms of built-in functions, or subqueries

Is SPARQL the only one ?

Some previous attempts to query SPARQL include:

reactive-rule languages – e.g. Algea

path-based languages – e.g. Versa

relational-based – TRIPLE, Xcerpt, SeRQL

At present

SPARQL is **The standard** for querying RDF.

SPARQL Query Language Basics

Query Types

SELECT – returns a binding table (similarly to SQL)

Query Types

SELECT – returns a binding table (similarly to SQL)

ASK – returns a true/false indicating existence of the given pattern in the RDF graph

Query Types

SELECT – returns a binding table (similarly to SQL)

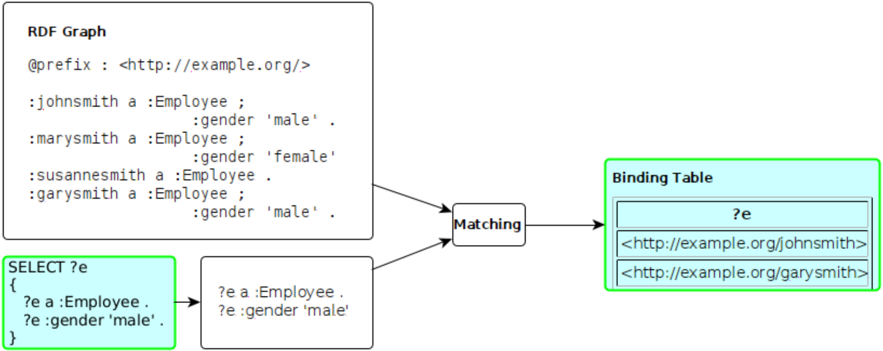
ASK – returns a true/false indicating existence of the given pattern in the RDF graph

CONSTRUCT – returns an RDF graph constructed from the binding table

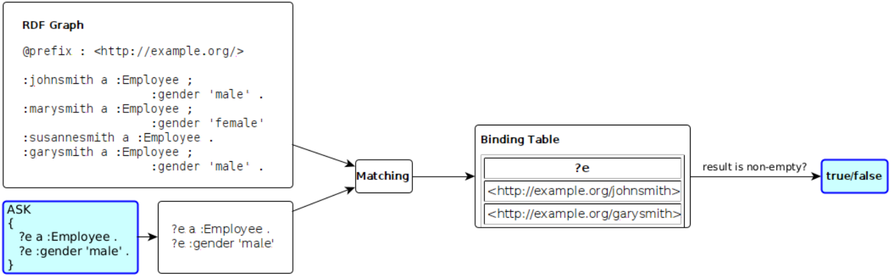
Query Types

- SELECT – returns a binding table (similarly to SQL)
- ASK – returns a true/false indicating existence of the given pattern in the RDF graph
- CONSTRUCT – returns an RDF graph constructed from the binding table
- DESCRIBE – returns an RDF graph describing the given resource (semantics not fixed)

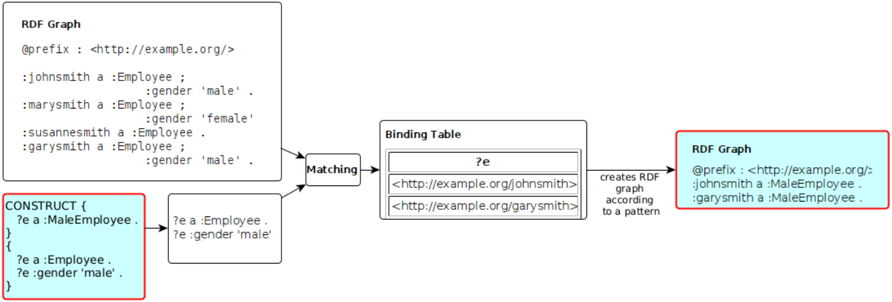
Select Evaluation



Ask Evaluation



Construct Evaluation



Query Solutions

RDF Term $\in T = T_I \cup T_B \cup T_L$, being a union of set of all IRIs, blank nodes and literals respectively.

solution is a mapping $\mu : V \to T$ assigning an RDF term to each variable from the query,

result list is a list $R = (\mu_1, \ldots, \mu_n)$ of solutions,

example

Graph:

```
:John :hasName "John"@en
```

Query:

```
SELECT ?person ?personName {?person :hasName ?name}
```

Solution:

$\mu = \{(?\text{person} \to :\texttt{John}), (?\text{name} \to \text{"John"@}en)\}$

Graph Patterns

triple pattern (TP) is a member of $(T \cup V) \times (T_I \cup V) \times (T \cup V)$,

example

```
(?person,a,foaf:Person)
```

or in the turtle syntax

```
?person a foaf:Person .
```

basic graph pattern (BGP) is a set $BGP = \{TP_1, \ldots, TP_n\}$ of triple patterns.

example

```
?person a foaf:Person .
?person rdfs:label ?label .
```

Basic Graph Patterns

Repository content

```
@prefix : <http://example.org/>
@prefix r: <http://dbpedia.org/resource/>
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
r:Thomas_Edison :invented :Bulb .
r:J_Cimrman :invented :Bulb .
:Bulb rdfs:label "Bulb"@en , "Zarovka"@cs .
:Wheel rdfs:label "Wheel"@en .
:Gunpowder rdfs:label "Strelny prach"@cs .
```

Query with a BGP

```
PREFIX : <http://example.org/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?s ?l
WHERE {
  ?s :invented ?i.
  ?i rdfs:label ?l.
}
```

Results

s	l
r:Thomas_Edison	“Bulb”@en
r:J_Cimrman	“Bulb”@en
r:Thomas_Edison	“Zarovka”@cs
r:J_Cimrman	“Zarovka”@cs

Basic Graph Patterns

Repository content

```
@prefix : <http://example.org/>
@prefix r: <http://dbpedia.org/resource/>
@prefix rdfs:
↪ <http://www.w3.org/2000/01/rdf-schema#>
r:Thomas_Edison :invented :Bulb .
r:J_Cimrman :invented :Bulb .
:Bulb rdfs:label "Bulb"@en , "Zarovka"@cs .
:Wheel rdfs:label "Wheel"@en .
_:x :invented :Wheel .
_:y :invented :SteamEngine .
_:z :invented :Gunpowder .
:Gunpowder rdfs:label "Strelny prach"@cs .
```

Query with a BGP

```
PREFIX : <http://example.org/>
PREFIX rdfs:
↪ <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?s ?l
WHERE {
  ?s :invented ?i.
  ?i rdfs:label ?l.}
```

Results

s	l
r:Thomas_Edison	“Bulb”@en
r:J_Cimrman	“Bulb”@en
r:Thomas_Edison	“Zarovka”@cs
r:J_Cimrman	“Zarovka”@cs
_:a	“Wheel”@en
_:b	“Strelny prach”@cs

Filtering results

Description

syntax BGP1 **FILTER**(boolean condition) BGP1

description **FILTER** clause filters BGP results (anywhere in a BGP)

Query with a BGP

```
PREFIX : <http://example.org/>
PREFIX rdfs:
↪ <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?s ?l
WHERE {
  ?s :invented ?i.
  ?i rdfs:label ?l
  FILTER(regex(?l,"^.ul.*")
    && contains(str(?s),"Cimr"))
}
```

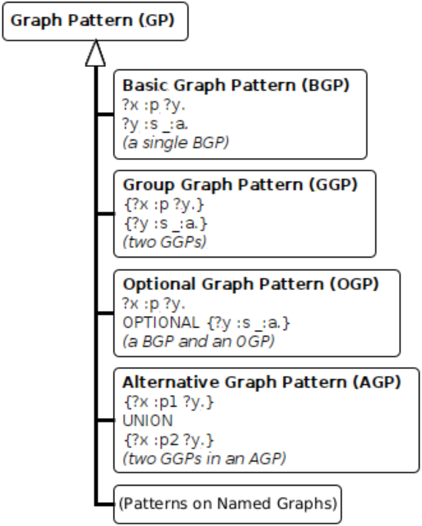
See SPARQL 1.1 spec.
https://www.w3.org/TR/2013/REC-sparql11-query-20130321/

- string functions – e.g. `strlen`, `contains`, `substr`, `concat`, `regex`, `replace`
- RDF term functions – e.g. `isIRI`, `IRI`, `isBlank`, `BNODE`, `isLiteral`, `str`, `lang`, `datatype`

Graph Patterns – Overview

Graph patterns cover all basic algebraic operations:

- conjunction as a sequence of graph patterns,
- disjunction as **UNION**,
- negation as **FILTER NOT EXISTS** or **MINUS**
- conditional conjunction as **OPTIONAL**



Optional data

Description

syntax GP1 **OPTIONAL** { GP2 }

description results of GP1 are optionally augmented with results of GP2, if any. Optionals are left-associative.

```
PREFIX : <http://example.org/>
PREFIX rdfs:
↪   <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?s ?i ?l
WHERE {
    ?s :invented ?i.
    OPTIONAL {
      ?i rdfs:label ?l
      FILTER (lang(?l)="en").
    }
    OPTIONAL {
      ?i rdfs:label ?l
      FILTER (lang(?l)="cs")
    }
}
```

Result set

s	l
r:Thomas_Edison	"Bulb"@en
r:J_Cimrman	"Bulb"@en
_:a	"Wheel"@en
_:b	
_:c	"Strelny prach"@cs

FILTERing with regular expressions

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
SELECT ?title
WHERE {
  ?x dc:title ?title .
  ?x dc:author ?author
  FILTER regex(?title, ".SPARQL")
}
```

Order of OPTIONALs might be important

```
PREFIX rdf:
 ↪  <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX books: <http://books.example.org>
SELECT ?writing ?name
WHERE
{
  ?writing rdf:type books:Essay .
  OPTIONAL {
    ?writing books:translator ?p .
    ?p dc:name ?name .
  } .
  OPTIONAL {
    ?writing books:author ?p .
    ?p dc:name ?name .
  }
}
```

Negation

negation as failure – i.e. what cannot be inferred is considered false.

MINUS

```
...
SELECT ?s1 ?i
{
  ?s1 :invented ?i.
  MINUS {
    ?s2 :invented ?i .
    FILTER(?s1 != ?s2) .
  }
}
```

Variable `?s1` is not bound in the **MINUS** pattern. Returns all inventors.

FILTER NOT EXISTS

```
...
SELECT ?s1 ?i
{
  ?s1 :invented ?i.
  FILTER NOT EXISTS {
    ?s2 :invented ?i .
    FILTER(?s1 != ?s2).
  }
}
```

Returns all inventions that were invented just by one inventor.

Property Paths

Description

Property paths allow to express simple regular expressions on properties, as follows

syntax	matches ($e_{(i)}$ means path element, $p_{(i)}$ means *iri* or ˆ*iri*)
iri	an IRI (path of length 1)
$\hat{}e$	an inverse path (o $\rightarrow$ s)
e_1 / e_2	a sequence path of e_1 followed by e_2
e_1 | e_2	an alternative path of e_1 or e_2
$e*$	a sequence path of zero or more matches of e
$e+$	a sequence path of one or more matches of e
$e?$	a sequence path of zero or one more matches of e
$!(p_1 \| \ldots \| p_n)$	any IRI not matching any of p_i
(e)	group path (brackets for precedence)

Get the name of a resource

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
PREFIX rdfs:
↪ <http://www.w3.org/2000/01/rdf-schema#>
SELECT *
{
    ?s rdfs:label|dc:title ?name.
}
```

Get elements of an RDF collection

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
PREFIX rdfs:
 ↪  <http://www.w3.org/2000/01/rdf-schema#>
SELECT *
{
    ?s (rdf:rest*)/rdf:first ?listItem.
}
```

Aggregations

Description

Similarly to SQL, SPARQL allows using aggregation functions for numeric/sting data:

COUNT `(?var)`, or **COUNT** `(DISTINCT ?var)` – counts number of (distinct) occurences of `?var` in the resultset,

MIN `(?v)`, **MAX** `(?v)`, **SUM** `(?v)`, **AVG** `(?v)` – similar to their SQL counterparts,

GROUP_CONCAT `(?var; separator = <SEP>)` **AS** `?group)` – concatenates all elements in the group with the given separator character,

SAMPLE – takes an arbitrary representative from the group.

Usage of `(?expr` **AS** `?var)` alias is obligatory.

Similarly to SQL, SPARQL allows computing aggregates over particular data groups and filter in them using **GROUP BY**/**HAVING** construct.

Compute the number of inventors of each invention.

```
PREFIX : <http://example.org/>
PREFIX rdfs:
 ↪ <http://www.w3.org/2000/01/rdf-schema#>
SELECT
    (COUNT(?s) AS ?count)
    ?i
    (GROUP_CONCAT(?s;separator=",") AS ?inventors)
WHERE {
    ?s :invented ?i.
}
GROUP BY ?i
HAVING (COUNT(?s) > 1)
```

Compute the number of inventions of each inventor.

Description

Variables can be assigned results of function (or aggregation function). The syntax is `BIND (expr AS ?v)`, where `expr` is an expression and `?v` is the newly create variable not appearing before.

```
PREFIX : <http://example.org/>
PREFIX rdfs:
 ↪ <http://www.w3.org/2000/01/rdf-schema#>
SELECT (COUNT(?s) AS ?count) ?invention
WHERE {
    ?s :invented ?i .
    ?i rdfs:label ?l
    BIND (concat("Invention: ",?l) AS ?invention)
}
GROUP BY ?i ?invention
```

Distributed Queries

Syntax and semantics

syntax …**SERVICE** (**SILENT**) sparqlServiceURI { GP }

semantics this clause poses a sparql query described by graph pattern GP to a remote SPARQL endpoint *sparqlServiceURI*

DBPedia service query

```
PREFIX : <http://example.org/>
PREFIX p: <http://dbpedia.org/property/>
PREFIX r: <http://dbpedia.org/resource/>
SELECT ?s ?p ?o ?i
WHERE {
  ?s :invented ?i.
  OPTIONAL { SERVICE SILENT
       <http://dbpedia.org/sparql> {
     ?s ?p ?o
      FILTER( strstarts(str(?p),
            concat(str(p:),"death")) ) }}}
```

Local repo content

```
@prefix : <http://example.org/>
@prefix p:
↪   <http://dbpedia.org/property/>
@prefix r:
↪   <http://dbpedia.org/resource/>
:inventors {
  r:Thomas_Edison :invented :bulb.
  r:J_Cimrman :invented :bulb.
}
```

Other Features

- **VALUES** – predefined variable bindining specified in the tabular form

Other Features

- **VALUES** – predefined variable bindining specified in the tabular form
- **ORDER BY, LIMIT, OFFSET** – used analogously to SQL

Other Features

- **VALUES** – predefined variable bindining specified in the tabular form
- **ORDER BY, LIMIT, OFFSET** – used analogously to SQL
- **FROM, FROM NAMED** – used to specify active default/named graphs for the query

Other Features

- **VALUES** – predefined variable bindining specified in the tabular form
- **ORDER BY, LIMIT, OFFSET** – used analogously to SQL
- **FROM, FROM NAMED** – used to specify active default/named graphs for the query
- **SELECT DISTINCT** – removes duplicates from the results

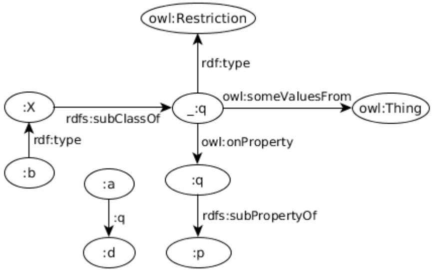
SPARQL Entailment Regimes

- SPARQL [**Harris:13:SQL**] defines evaluation of BGPs w.r.t. *simple entailment*
- [**Ogbuji:13:SER**] defines a several other entailment regimes for SPARQL BGPs:
  - RDF entailment, RDFS entailment, D-entailment , as defined in RDF spec.
  - OWL 2 entailments, RIF entailment , that are more expressive (refer to OWL lecture).
  - . . . conditions for defining custom entailment regimes

All SPARQL entailment regimes must ensure

- compliance with the corresponding entailment (e.g. RDF, RDFS)
- finiteness of results
  - only *canonical* b-nodes can be returned (ensured by skolemization of both the query and the queried graph),
  - only finite part of respective vocabularies can be returned as query results (e.g. RDF vocabulary without `rdf:_n` properties not occuring

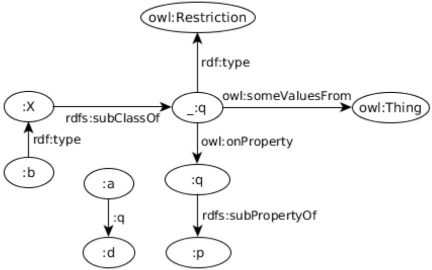
SPARQL Evaluation Semantics




```
PREFIX : <http://ex.org/e1>
SELECT ?x
WHERE { ?x :p :d }
```

Simple-entailment No result.

SPARQL Evaluation Semantics

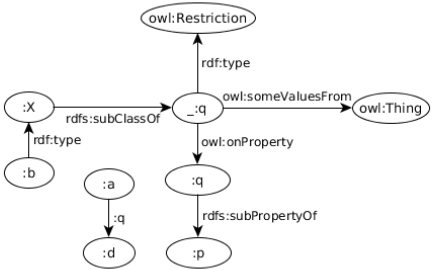



```
PREFIX : <http://ex.org/e1>
SELECT ?x
WHERE { ?x :p :d }
```

Simple-entailment No result.

RDF-entailment No result.

SPARQL Evaluation Semantics



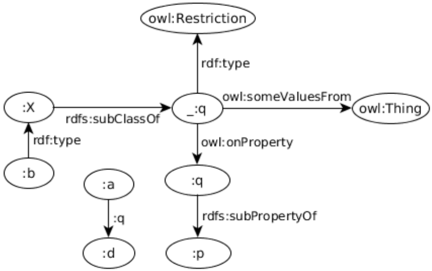

```
PREFIX : <http://ex.org/e1>
SELECT ?x
WHERE { ?x :p :d }
```

Simple-entailment No result.

RDF-entailment No result.

RDFS-entailment One result: `?x=:a`.

SPARQL Evaluation Semantics




```
PREFIX : <http://ex.org/e1>
SELECT ?x
WHERE { ?x :p :d }
```

Simple-entailment No result.

RDF-entailment No result.

RDFS-entailment One result: `?x=:a`.

OWL-entailment Two results: `?x=:a` and `?x=:b`.

SPARQL SELECT/ASK results

CSV
: for **SELECT**; loses information about datatypes/langs of RDF terms

TSV
: for **SELECT**; is lossless

XML, JSON
: for **SELECT,ASK**; is lossless, supports additional information (e.g. columns identification through *link* attribute),

```
{
  "head": {
    "vars": [ "person", "name" ]
  },
  "results": {
    "bindings":
     [{
      "person": {
         "type": "uri",
         "value": "http://ex.com/p1"
         ↪   },
      "name": {
         "type":"literal",
         "value": "Smith" }
     },{
      "person": {
         "type": "uri",
         "value": "http://ex.com/p2"
         ↪   }
     }]
  },
}
```

Related Technologies

SPIN (SPARQL inference notation) – SPARQL rules encoded in RDF (`http://spinrdf.org/`)

Related Technologies

SPIN (SPARQL inference notation) – SPARQL rules encoded in RDF (`http://spinrdf.org/`)

iSPARQL – SPARQL visual query builder (`http://oat.openlinksw.com/isparql/`)

Related Technologies

SPIN (SPARQL inference notation) – SPARQL rules encoded in RDF (http://spinrdf.org/)

iSPARQL – SPARQL visual query builder (http://oat.openlinksw.com/isparql/)

SHACL – Shapes Constraint Language (https://shacl.org/playground/)

Related Technologies

- **SPIN** (SPARQL inference notation) – SPARQL rules encoded in RDF (`http://spinrdf.org/`)
- **iSPARQL** – SPARQL visual query builder (`http://oat.openlinksw.com/isparql/`)
- **SHACL** – Shapes Constraint Language (`https://shacl.org/playground/`)
- **SQWRL** (Semantic Query-Enhanced Web Rule Language) – query language based on SWRL (see next lecture), `http://protege.cim3.net/cgi-bin/wiki.pl?SQWRL`

SPARQL Update (Graph Update Operations)

Inserting

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
INSERT { <http://example/person> dc:title  "John" }
WHERE {}
```

Deleting

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
DELETE WHERE
  ?person a foaf:Person .
}
```

Replacing

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dbo: <http://dbpedia.org/ontology/>
DELETE { ?person a foaf:Person . }
INSERT { ?person a dbo:Person . }
WHERE { ?person a foaf:Person . }
```

Other operations

- LOAD – loading a graph into a graph store
- CLEAR – clearing a graph inside a graph store
- CREATE – create a new graph in a graph store
- DROP – deletes a graph in a graph store
- COPY – inserts all triples from one graph to another, clearing the dest.
- MOVE – moves all triples from one graph to another
- ADD – inserts all triples from one graph to another, keeping the dest.

See `https://www.w3.org/TR/sparql11-update/` for details