

1 Introduction

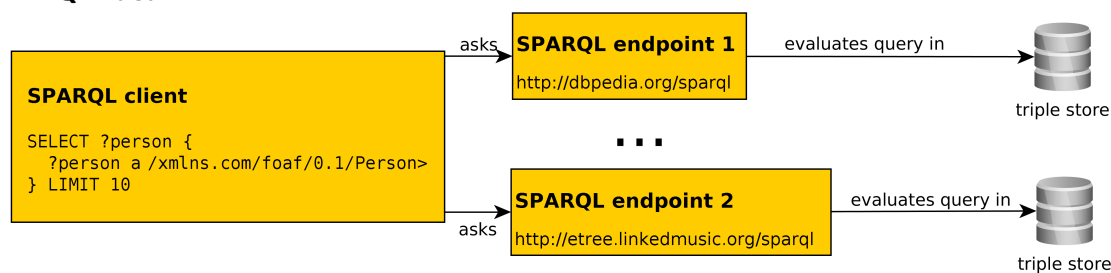
1.1 SPARQL

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 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. In addition, graph languages have been gaining popularity for querying RDF (e.g. GraphQL <https://graphql.org/>).

1.1.1 SPARQL Basics

Query Types

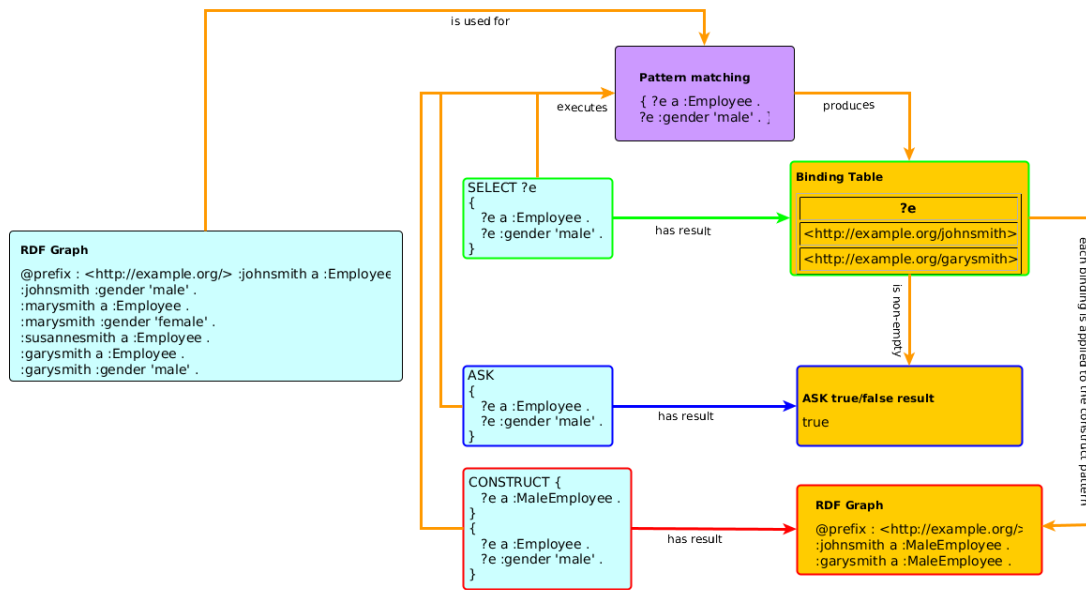
SELECT – returns a binding table (similarly to SQL)

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)

Query Evaluation



Basic Definitions (1)

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.

example

`_:a <http://example.org/data/John> "John"@en`

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

example

$$\mu = \{ (?person \rightarrow \langle \text{http} : // \text{example.org} / \text{data} / \text{John} \rangle), \\ (?personName \rightarrow "John"@en) \}$$

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

Basic Definitions (2)

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

example

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

or in the turtle syntax

`?person a foaf : Person`

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

example

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

graph store is a mutable container providing an RDF dataset at each time,

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#>
:inventors {
  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.}
```

Table 1.1: Result set

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"))
}

```

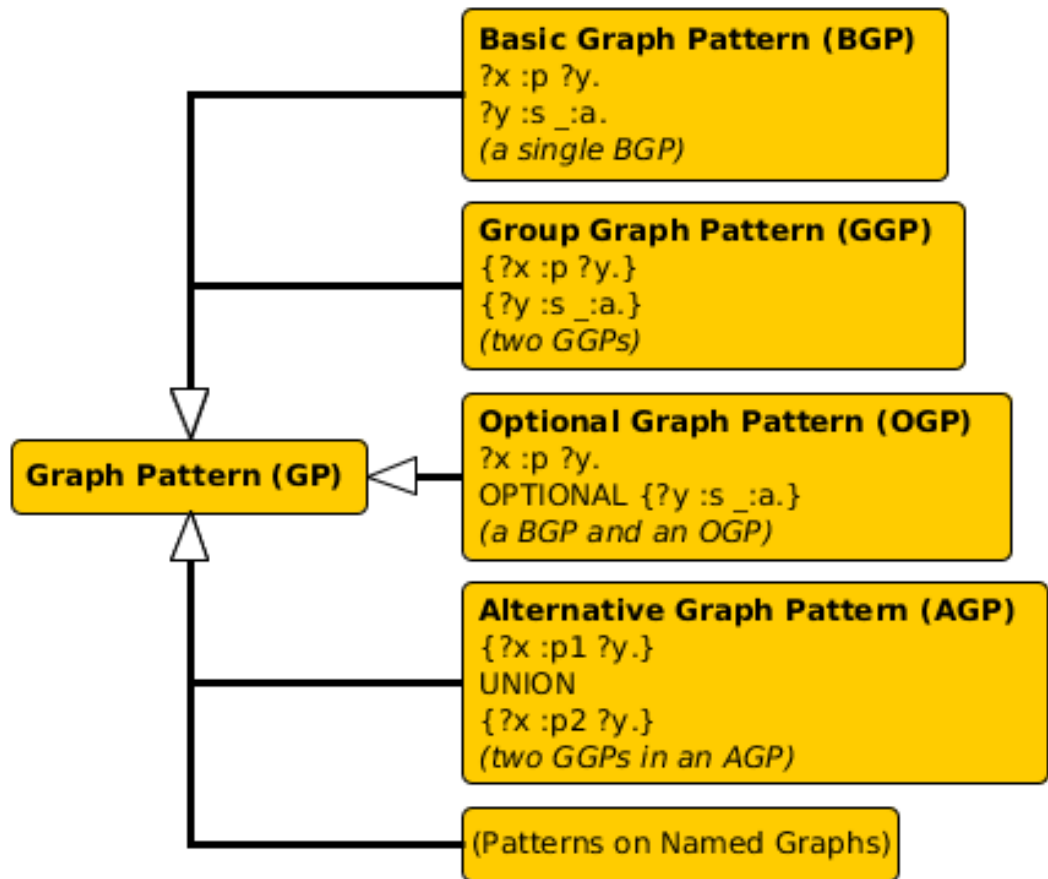
See SPARQL 1.1 spec. <https://www.w3.org/TR/2013/REC-sparql11-query-20130321/#func-rdfTerms>

- 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 (sequence of graph patterns),
- disjunction (**UNION** pattern),
- negation (**FILTER NOT EXISTS**, **MINUS**)
- conditional conjunction (**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.

Two optionals

```
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")
  }
}

```

Table 1.2: Result set

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

Other examples

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.

two constructs – **MINUS** vs. **FILTER NOT EXISTS**

MINUS

```

PREFIX : <http://example.org/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
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**

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```
PREFIX : <http://example.org/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
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 \hat{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
$!(p_1 \dots p_n)$	any IRI not matching any of p_i
(e)	group path (brackets for precedence)

Property Paths – Examples

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 (rdfs:rest*)/rdfs:first ?listItem.
}
```

Aggregations

Description

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

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

MIN(?v), **MAX(?v)**, **SUM(?v)**, **AVG(?v)** – analogous 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.

Aggregation – Examples

Compute the number of inventions of each inventor.

```
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)
FROM :inventors
WHERE {
    ?s :invented ?i.
}
GROUP BY ?i
HAVING (COUNT(?s) > 1)
```

Variable assignment

Description

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

Compute the number of inventions of each inventor.

```
PREFIX : <http://example.org/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT (COUNT(?s) AS ?count) ?invention
FROM :inventors
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 }

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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 {
  GRAPH :inventors { ?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_Cimman :invented :bulb.
}
```

Selected Other Features

- **VALUES** – predefined variable binding 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

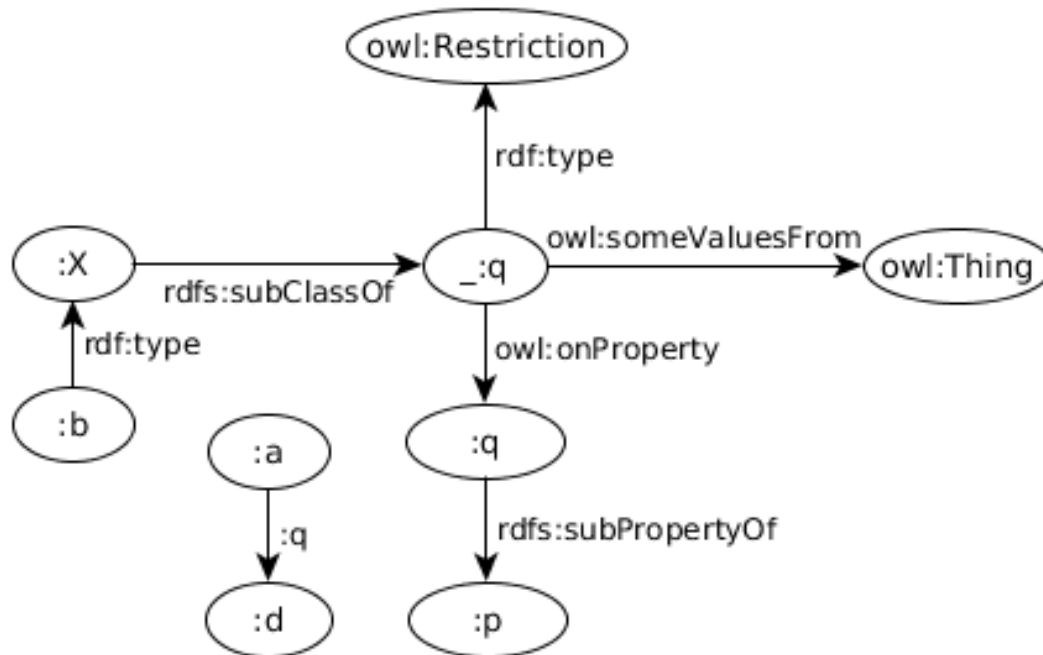
- simply – SPARQL spec. [Harris:13:SQL] defines evaluation of BGPs w.r.t. *simple entailment*
- [Ogbuji:13:SER] defines a several other entailment regimes for SPARQL BGPs: **RDF entailment**, **RDFS entailment**, **D-entailment** , as defined in RDF spec. **OWL 2 entailments**, **RIF entailment** , that are the much more expressive, see lecture 10.
... 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 occurring in the graph).

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/languages of RDF terms

TSV for **SELECT**; is lossless

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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/>)

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

SNORQL – Web front-end for exploring SPARQL endpoints (<https://github.com/kurtjx/SNORQL>)

SeRQL – Sesame query language (alternative to SPARQL)

SQWRL (Semantic Query-Enhanced Web Rule Language) – query language based on SWRL (see next lecture), <http://protege.cim3.net/cgi-bin/wiki.pl?SQWRL>

1.1.2 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/>
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 new 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