

1 Introduction

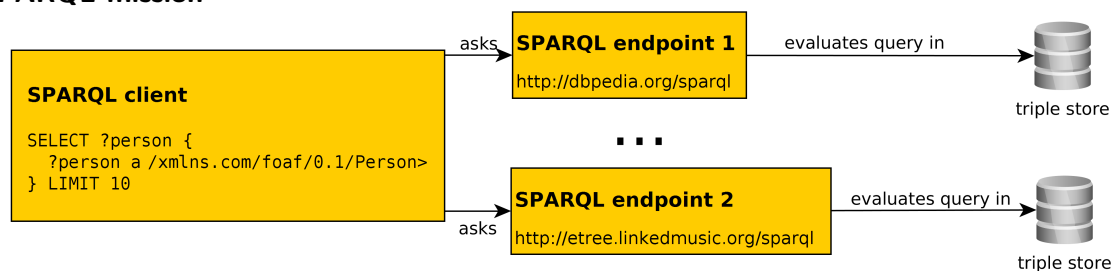
1.1 SPARQL

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 mission



Factsheet

- SPARQL 1.1 – 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 1.2 – W3C Working Draft (September 2024) – mainly support for RDF 1.2 (triple term patterns)

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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.

1.1.1 SPARQL Query Language Basics

Query Types

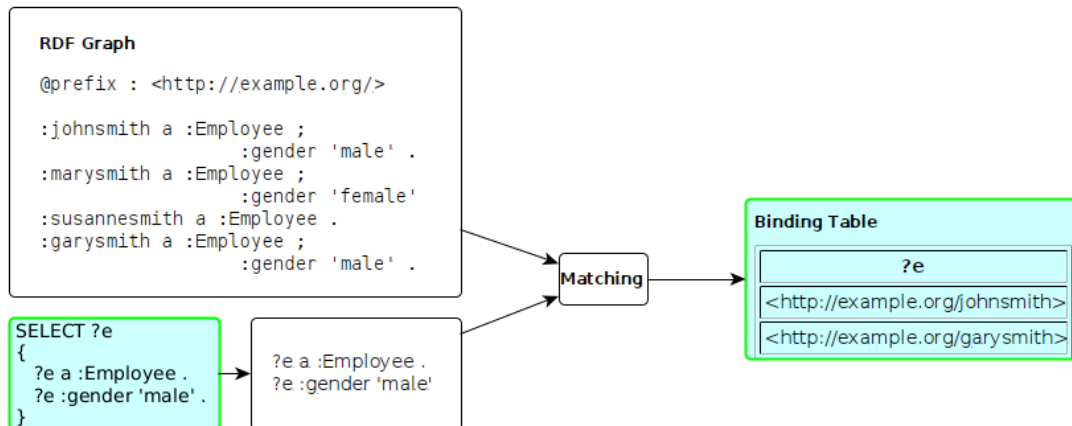
SELECT – returns a binding table (similarly to SQL)

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

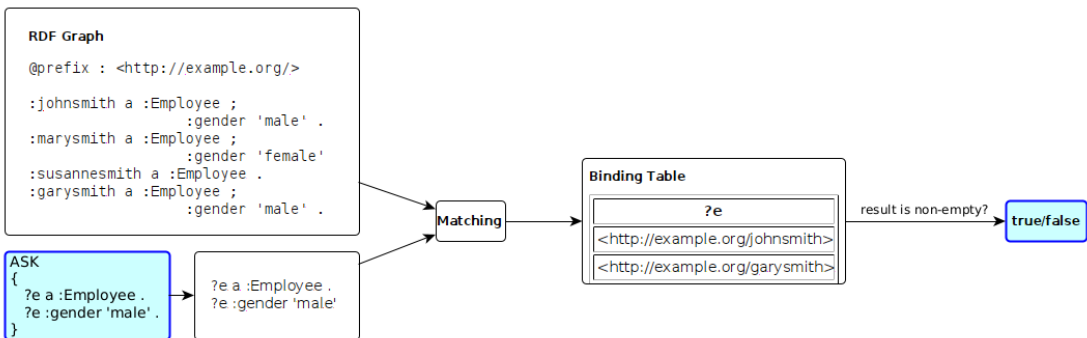
CONSTRUCT – returns an RDF graph constructed from the binding table

DESCRIBE – returns an RDF graph describing the given resource (semantics not fixed)

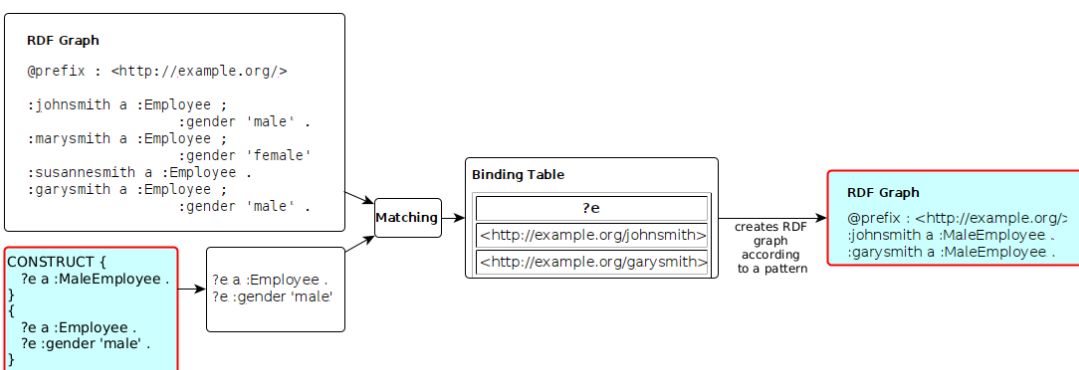
Select Evaluation



Ask Evaluation



Construct Evaluation



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

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

example

Graph:

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

Query:

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

Solution:

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

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 $BGP = \{TP_1, \dots, TP_n\}$ 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 {

```

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```
?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

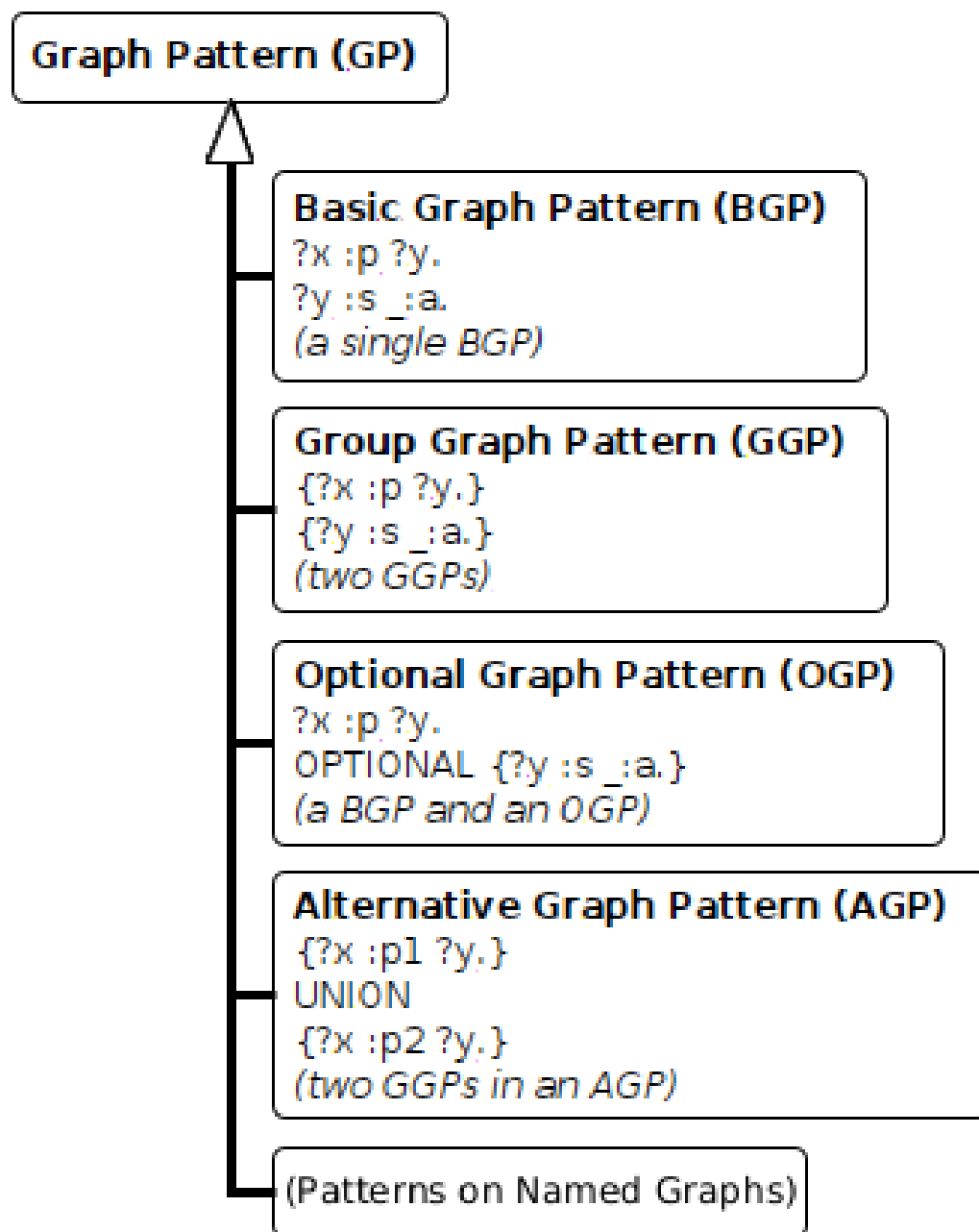
Graph patterns cover all basic algebraic operations:

conjunction 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 }

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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.

MINUS vs. FILTER NOT EXISTS – another example

```

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

```

Returns ALL results.

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

Returns NO results.

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 <i>iri</i> or $\hat{iri}$)
<i>iri</i>	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)

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/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)** – 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
```

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```
    BIND (concat ("Invention: ", ?i) 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 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

- 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.

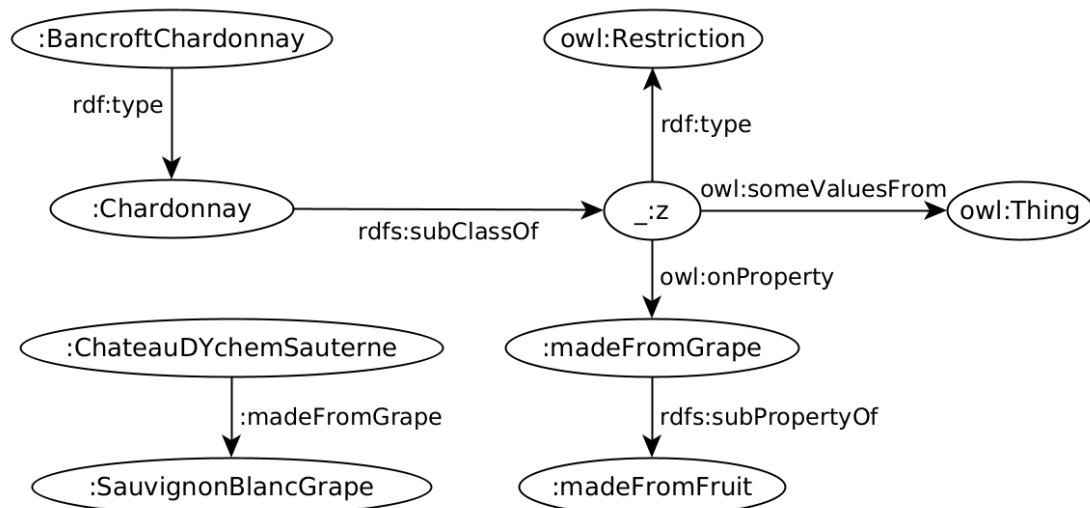
OWL 2 entailments, RIF entailment , that are more expressive (refer to OWL lecture).

... 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 occurring in the graph).

SPARQL Evaluation Semantics



```

PREFIX : <http://ex.org/el>
SELECT ?x
WHERE { ?x :madeFromFruit _:d }
  
```

Simple-entailment No result.

RDF-entailment No result.

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

OWL-entailment Two results: `?x=:ChateauDYchemSauterne` and `?x=:BancroftChardonnay`.

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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/>)

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>

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 {}
```

or simply

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

Deleting

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

or simply

```
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