SPARQL 1.0

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Overview

1. Introduction to SPARQL
2. SPARQL Basics
3. Updating Linked Data with SPARQL 1.1
4. SPARQL Protocol

INTRODUCTION TO SPARQL

Parts of the SPARQL Specification

- SPARQL Query Language *(discussed here)*
  - declarative query language for RDF data
  - SPARQL 1.0 : W3C Specification since January 2008
    - http://www.w3.org/TR/rdf-sparql-query/
  - SPARQL 1.1: W3C Specification since March 2013
    - http://www.w3.org/TR/sparql11-query/
- SPARQL Update Language *(discussed here)*
  - Declarative manipulation language for RDF data
  - http://www.w3.org/TR/sparql11-update/
- SPARQL Protocol *(discussed here)*
  - Standard for issuing SPARQL queries and receiving results
  - Used for the communication between SPARQL services and clients
  - http://www.w3.org/TR/sparql11-protocol/
- SPARQL Query Results XML Format *(not discussed here)*
  - http://www.w3.org/TR/rdf-sparql-XMLres/

SPARQL 1.1

- **SPARQL 1.0** only allows accessing the data (**query**)
- **SPARQL 1.1** introduces:

Query extensions
- Aggregates, subqueries, negation, expressions in the SELECT clause, property paths, assignment, short form for CONSTRUCT, expanded set of functions and operators

Updates
- **Data management**: Insert, Delete, Delete/Insert
- **Graph management**: Create, Load, Clear, Drop, Copy, Move, Add

Federation extension
- Service, values, service variables (informative)

SPARQL BASICS

Data representation

- Data will be represented in the Turtle format
- Turtle also used in SPARQL queries (in the representation of triple pattern- *to see later*)

T1 **dbpedia:Good_Day_Sunshine dbpedia-owl:artist dbpedia:The_Beatles .**

T2	dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .
T3	**dbpedia:Yellow_Submarine_(album) dbpedia-owl:artist dbpedia:The_Beatles .**
T4	dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Rock_music .
T5	**dbpedia:The_Beatles dbprop:alt "A square quartered into four head shots of young men with moptop haircuts. All four wear white shirts and dark coats." .**

SPARQL Basics

- **RDF triple:** Basic building block of the form *(subject, predicate, object)*

	Subject	*Predicate*	*object*
T1:	dbpedia:The_Beatles	foaf:name	"The Beatles"
T2:	**dbpedia:Help!_(album)**	**dbpedia-owl:artist**	**dbpedia:The_Beatles**
T3:	dbpedia:The_Beatles	dbpedia-owl:genre	dbpedia:Rock_music

SPARQL Basics

- SPARQL is based on **Pattern Matching**
  - Queries describe ***subgraphs*** of the queried graph
  - **SPARQL *graph patterns*** describe the subgraphs to match
- **SPARQL Graph Patterns**
  - **Triple Pattern:** *triple with variables*
  - **Group Graph Patterns**: *composition of Group Graph Patterns* using SPARQL *operators*
    - **Basic Graph Patterns:** *sets of triple patterns*
    - **Filters:** *complex conditions/constraints*
    - **Union** Graph Patterns
    - **Optional** Graph Patterns
  - Patterns on **Named Graphs**

SPARQL Triple Pattern

- **Triple Pattern**
  - **An RDF triple** with **variables** in the place of *subject*, *predicate*, *object*
  - **Variables** are **prefixed** with "?"

TP1:	`?album dbpedia-owl:artist dbpedia:The_Beatles`
TP2:	**`?album ?property "Help!" .`**
TP3:	`?album ?property ?object .`

  - `?album, ?property, ?object` are **variables**

SPARQL Basic Graph Pattern

- A **Basic Graph Pattern (BGP)** is a ***set of triple patterns***
- A **BGP** is understood as a conjunction of the triple patterns it consists of

	Triple Patterns
TP1	dbpedia:Help!_(album) dbpedia-owl:artist ?artist .
TP2	**?artist dbpedia-owl:genre ?genre .**

	Basic Graph Pattern
BGP1	dbpedia:Help!_(album) dbpedia-owl:artist ?artist . ?artist dbpedia-owl:genre ?genre .

SPARQL Group Graph Pattern

- A **group graph pattern:** a *set of graph patterns* delimited by { }

	Group Graph Patterns
GGP1.	`{ dbpedia:Help!_(album) dbpedia-owl:artist ?artist . ?artist dbpedia-owl:genre ?genre }`
GGP2.	**`{ dbpedia:Help!_(album) dbpedia-owl:artist ?artist . ?artist dbpedia-owl:genre ?genre . }`**
GGP3.	`{ { dbpedia:Help!_(album) dbpedia-owl:artist ?artist } . { ?artist dbpedia-owl:genre ?genre} . }`

Equivalent group graph patterns:

- When a graph pattern consists of only **basic graph patterns**, then they are all **interpreted conjunctively**
- The group graph pattern is ***equivalent*** *to the corresponding set of triple patterns*

SPARQL Group Graph Patterns

- **Group Graph Patterns**
  - built through **inductive construction** combining smaller patterns into more complex ones using SPARQL operators *(to define later)*
  - Variables in group graph patterns have ***a global scope***
  - **Empty Group Graph Pattern:** special case of graph pattern denoted by **{ }**

Note: There is *no keyword* for *conjunction* in SPARQL.
Basic graph patterns (BGPs) are simply juxtaposed
and then enclosed in **"{"** and **"}"** to form a group graph pattern.

SPARQL Query Results

- **Subgraphs** of the data that **match** the SPARQL Query
- **Matching** based on ***variable bindings/mappings***
- **Binding/Mapping:**
  - **substitution of query variables** with **RDF terms**
  - perceived as **partial function** from variables to RDF terms
  - represents one possible way of variables substitution
  - ***not all variables need to be bound in a mapping***
  - tabular representation: each row represents one mapping

Mapping	?v1	?v2	?v3	….	?vk
μ_1	*val1*	*val2*	*val3*	….	*valk*

Solution: bags of variable bindings

Mapping	?v1	?v2	?v3	….	?vk
μ_1	*v1*	*v2*	*v3*	….	*vk*
μ_2	*u1*	*u2*	*u3*	….	*um*

Matching Triple Patterns (1)

- Result: the *triples* that match the *variables in the triple pattern*

Triple Pattern

TP1:	**?work dbpedia-owl:artist ?artist .**

RDF Triples

T1	**dbpedia:Good_Day_Sunshine dbpedia-owl:artist dbpedia:The_Beatles .**
T2	dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .
T3	**dbpedia:Yellow_Submarine_(album) dbpedia-owl:artist dbpedia:The_Beatles .**
T4	dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Rock_music .
T5	**dbpedia:The_Beatles dbprop:alt "A square quartered into four head shots of young men with moptop haircuts. All four wear white shirts and dark coats." .**

Mappings

Mapping	?work	?artist
μ_1	dbpedia:Good_Day_Sunshine	dbpedia:The_Beatles
μ_2	dbpedia:Help!_(album)	dbpedia:The_Beatles
μ_3	dbpedia:Yellow_Submarine_(album)	dbpedia:The_Beatles

Matching Basic Graph Patterns (2)

- Result:
  - *all the triple patterns* should **match** *(conjunction)*
  - *all variables* must be **bound**

BGP1:

```
{ dbpedia:Help!_(album) dbpedia-owl:artist ?artist .
  ?artist dbpedia-owl:genre ?genre . }
```

T1	**dbpedia:Good_Day_Sunshine dbpedia-owl:artist dbpedia:The_Beatles .**
T2	dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .
T4	dbpedia:The_Beatles dbprop:alt "A square quartered into four head shots of young men with moptop haircuts. All four wear white shirts and dark coats." .
T3	dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Pop_music .

Mappings	?artist	?genre
μ_1	dbpedia:The_Beatles	dbpedia:Pop_music

Matching Basic Graph Patterns (3)

BGP1:

```
{ dbpedia:Help!_(album) dbpedia-owl:artist ?artist .
  ?artist dbpedia-owl:genre ?genre . }
```

T1 dbpedia:Good_Day_Sunshine dbpedia-owl:artist dbpedia:The_Beatles .

T2 dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .

T3 dbpedia:Yellow_Submarine_(album) dbpedia-owl:artist dbpedia:The_Beatles .

T4 dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Pop_music .

T5 dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Rock_music .

Mappings	?artist	?genre
μ_1	dbpedia:The_Beatles	dbpedia:Pop_music
μ_2	dbpedia:The_Beatles	dbpedia:Rock_music

Filters

- *Impose* ***constraints*** on group graph patterns not only on variables
- Constraints involve:
  - ***Arithmetic operators*** (+,-,*,/)
  - ***RDF specific functions*** `(isLiteral(), Lang(), Bound(),…)`
  - ***Comparisons*** (=,<,>,<=,>=,!=)
  - ***Logical Connectives****:* negation (!), disjunction (||), conjunction (&&)
- Expressed using the **`FILTER`** keyword

F1.	`FILTER (isLiteral(?name))`
F2.	**`FILTER (?name = “The Beatles” )`**
F3.	`FILTER (?name = “The Beatles || ?name=“the beatles”)`
F4.	**`FILTER(REGEX(?name, “*beat*”, i))`**
F5.	`FILTER ( ?runtime> 1720 || ?runtime< 1000 ))`

- **Matching*: compute solutions*** and then ***filter out those*** that ***do not satisfy*** the constraint

Matching Filters

- A **FILTER** condition is a *restriction on solutions over the whole group in which the filter appears*
- A group graph pattern can have ***multiple filters.*** These *can be rewritten as a single filter with conjoined filter conditions*

```
FILTER(?name="The Beatles") .
FILTER (?runtime > 1720 ||
        ?runtime < 1200) .
```

```
FILTER( (?name="The Beatles") &&
        (?runtime > 1720 ||
         ?runtime < 1200) ) .
```

Equivalent Graph Patterns

F1.	**?artist dbpprop:name ?name . FILTER (?name = "The Beatles")**
F2.	**?artist dbpprop:name "The Beatles" .**

Filter Expressions

Type of function	*Function*	*Result type*
Functional Forms	bound	xsd:boolean
	IF	rdfTerm
	COALESCE	rdfTerm
	NOT EXISTS, EXISTS	xsd:boolean
	or, and	xsd:boolean
	RDFTerm-equal (=), sameTerm	xsd:boolean
	IN, NOT IN	boolean
Functions on RDF Terms	isIRI, isBlank, isLiteral, isNumeric	xsd:boolean
	str, lang,	simple literal
	datatype	iri
	IRI	iri
	BNODE	blank node
Functions on Numerics	ABS, ROUND, CEIL, FLOOR	numeric
	RAND	xsd:double

Source:http://www.w3.org/TR/sparql11-query/#SparqlOps

Filter Expressions

Type of function	*Function*	*Result type*
Functions on Strings	STRLEN	xsd:integer
	SUBSTR, UCASE, LCASE	string literal
	STRSTARTS, STRENDS, CONTAINS	xsd:boolean literal
	STRBEFORE, STRAFTER	simple literal
	ENCODE_FOR_URI	string literal
	CONCAT	xsd:boolean
	langMatches	xsd:boolean
	REGEX	string literal
	REPLACE	
Functions on Dates and Times	now	xsd:dateTime
	year, month, day, hours, minutes	xsd:integer xsd:decimal
	seconds	xsd:dayTimeDuration
	timezone	simple literal
	tz	

Source:http://www.w3.org/TR/sparql11-query/#SparqlOps

Matching String Filters (1)

F1:

```
{ ?album dbpedia-owl:artist ?artist .
  ?artist dbpprop:name ?name .
  FILTER(?name="The Beatles") }
```

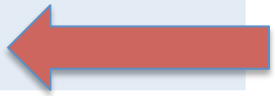
T1	dbpedia:Good_Day_Sunshine dbpedia-owl:artist dbpedia:The_Beatles.
T2	**dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .**
T3	dbpedia:Rain_Dogs dbpedia-owl:artist dbpedia:Tom_Waits
T4	**dbpedia:Tom_Waits dbpprop:name "Tom Waits" .**
T5	dbpedia:The_Beatles dbpprop:name "The Beatles" .

M	?album	?artist	?name
μ_1	dbpedia:Help!_(album)	dbpedia:The_Beatles	**"The Beatles"**
μ_2	dbpedia: Good_Day_Sunshine	dbpedia:The_Beatles	**"The Beatles"**
μ_3	dbpedia:Rain_Dogs	dbpedia:Tom_Waits	**"Tom Waits"**

Matching Arithmetic Filters (2)

F1:

```
{ ?album dbpedia-owl:runtime ?runtime .
  FILTER(?runtime > 1720 || ?runtime < 1200) }
```



T1	dbpedia:Good_Day_Sunshine dbpedia-owl:runtime 1290.000 .
T2	**dbpedia:Help!_(album) dbpedia-owl:runtime 1723.000 .**
T3	dbpedia:Help!_(album) dbpedia-owl:runtime 2060.000 .

M	?album	?runtime
μ_1	dbpedia:Help!_(album)	1723.000
μ_2	dbpedia:Help!_(album)	2060.000
μ_3	dbpe… Good_Day_…	…000

Union Graph Patterns

- ***What:*** allow the forming of ***disjunction of*** graph patterns
- ***Why****:* information is expressed in different ways in an RDF graph
- ***How*****:** Expressed using the **`UNION`** keyword

UGP1:

```
{ { ?artist dbpedia-owl:genre ?genre } UNION
  { ?artist mo:kind ?genre} }
```

- ***Matching:***
  - *More than one patterns may match* ***match***
  - If more than one patterns match, then ***all possible solutions are returned***
  - Patterns are matched independently and results are combined using ***set theoretic union***
  - ***Patterns do not necessarily use the same variables!***

Matching Union Graph Patterns (1)

```
UGP1:  { { ?artist dbpedia-owl:genre dbpedia:Pop_music }
       UNION
         { ?artist dbpedia-owl:genre dbpedia:Rock_music } }
```

```
T1  dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Pop_music .
T2  dbpedia:Tom_Waits dbpedia-owl:genre dbpedia:Rock_music .
T3  dbpedia:Tom_Waits dbpedia-owl:genre dbpedia:Experimental_music .
T4  dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Rock_music .
```

Mappings	?artist
μ_1	dbpedia:The_Beatles
μ_2	**dbpedia:Tom_Waits**
μ_3	dbpedia:The_Beatles

Matching Union Graph Patterns (2)

UGP1:	{ { ?album dbpedia-owl:artist ?artist } **UNION** { ?artist dbpedia-owl:genre ?genre } }

T1	dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Pop_music .
T2	dbpedia:Tom_Waits dbpedia-owl:genre dbpedia:Rock_music .
T3	**dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .**

M	?album	?artist	?genre
μ_1	dbpedia:Help!_(album)	dbpedia:The_Beatles	
μ_2		dbpedia:The_Beatles	dbpedia:Pop_music
μ_3		dbpedia:Tom_Waits	dbpedia:Rock_music

Matching Union Graph Patterns (3)

- Use of variables in the alternatives depends on what we want to compute

UGP1:

```
{ { ?album dbpedia-owl:artist ?artist1 } UNION
  { ?artist2 dbpedia-owl:genre ?genre } }
```

```
T1  dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Pop_music .
T2  dbpedia:Tom_Waits dbpedia-owl:genre dbpedia:Rock_music .
T3  dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .
```

M	?album	?artist1	?artist2	?genre
μ_1	dbpedia: Help!_(album)	dbpedia: The_Beatles		
μ_2			dbpedia: The_Beatles	dbpedia: Pop_music
μ_3			dbpedia: Tom_Waits	dbpedia: Rock_music

Semantics of Union Graph Patterns

- Union Graph Pattern UGP1 returns the same result as the set-theoretic union of the results of Graph Patterns GP1 and GP2

UGP1:	`{ { ?artist dbpedia-owl:genre dbpedia:Pop_music }`
	`  UNION`
	`  { ?artist dbpedia-owl:genre dbpedia:Rock_music } }`

GP1:	`{ ?artist dbpedia-owl:genre dbpedia:Pop_music . }`
GP2	`{ ?artist dbpedia-owl:genre dbpedia:Rock_music . }`

Properties of UNION

- **binary operator**
- **commutative operator**
  - `GP1 UNION GP2` **equivalent to** `GP2 UNION GP1`
- **left-associative**
- **has higher precedence than conjunction**
- `{ GP1 UNION GP2 } UNION GP3` **equivalent to**
  `GP1 UNION { GP2 UNION GP3 }`

Optional Graph Patterns

- ***What:*** allows the ***specification of optional parts*** of a query
- ***Why: regular and/or complete information*** cannot be assumed in all RDF graphs
- ***How:*** Expressed using the **OPTIONAL** keyword
  - GP1 **OPTIONAL** { GP2 }

OGP1:

```
{ ?album dbpedia-owl:artist ?artist }
OPTIONAL
{ ?album foaf:img ?img }
```

- ***Matching:***
  - If the optional part is not matched, no solutions for this part are created, but the solutions computed are not eliminated

Optional Graph Patterns

OGP1:

```
{ { ?album dbpedia-owl:artist ?artist } .
        OPTIONAL { ?artist dbpprop:birthDate ?date. } }
```

returns all mappings independently whether ?date is bound to some value

GP1:

```
{ ?album dbpedia-owl:artist ?artist .
   ?artist  dbpprop:birthDate ?date. FILTER (!BOUND(?date))
```

returns all mappings where ?date is not bound

GP2

```
{ ?album dbpedia-owl:artist ?artist .
   OPTIONAL { ?artist  dbpprop:birthDate ?date.
     FILTER (!BOUND(?date)) } }
```

Matching Optional Graph Patterns (1)

OGP1:	{ ?album dbpedia-owl:artist ?artist } **OPTIONAL** { ?album foaf:img ?img }

T1	dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .
T2	**dbpedia:Rain_Dogs foaf:img http://upload.wikimedia.org/wikipedia/commons/4/46TomWaitsRainDogs.jpg .**
T3	dbpedia:Rain_Dogs foaf:depiction http://en.wikipedia.org/wiki/Rain_Dogs#mediaviewer/File:TomWaitsRainDogs.jpg .
T4	**dbpedia:Rain_Dogs dbpedia-owl:artist dbpedia:Tom_Waits .**

Mappings	?album	?artist	?img
μ_1	dbpedia:Help!_(album)	dbpedia:The_Beatles	
μ_2	dbpedia:Rain_Dogs	**dbpedia:Tom_Waits**	http://upload.wikimedia.org/wikipedia/commons/4/46TomWaitsRainDogs.jpg

Properties of **OPTIONAL**

- **binary operator**
- **left associative**

  GP1 **OPTIONAL** { GP2 } **OPTIONAL** { GP3 }

  equivalent to

  {GP1 **OPTIONAL** { GP2 }} **OPTIONAL** { GP3 }

  – **But**

  {GP1 **OPTIONAL** GP2} **OPTIONAL** GP3

  not equivalent to

  GP1 **OPTIONAL** { GP2 **OPTIONAL** GP3 } .

- **not commutative**
- { **OPTIONAL** { GP1 } }
  equivalent to

  { {} **OPTIONAL** { GP1 } }
- **higher precedence than conjunction**

OPTIONALs and FILTERs

OGP1:	{ ?album dbpedia-owl:artist ?artist . **OPTIONAL** { ?album dbpedia-owl:runtime ?runtime.FILTER(?runtime >1720)}}

T1	dbpedia:Good_Day_Sunshine dbpedia-owl:runtime 1000.000
T2	**dbpedia:Help!_(album) dbpedia-owl:runtime 1723.000 .**
T3	dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .
T4	dbpedia:Rain_Dogs dbpedia-owl:artist dbpedia:Tom_Waits
T4	dbpedia:Good_Day_Sunshine dbpedia-owl:artist dbpedia:The_Beatles

Mapping	?album	?artist	?runtime
μ_1	dbpedia:Help!_(album)	dbpedia:The_Beatles	1723.000
μ_2	dbpedia:Rain_Dogs	dbpedia:Tom_Waits	

The OPTIONAL pattern ***does not generate any bindings*** when either

- **there is no** dbpedia-owl:runtime property (dbpedia:RainDogs)
- **there is** a dbpedia-owl:runtime property **but the constraint is not satisfied** (dbpedia:Good_Day_Sunshine)

Multiple OPTIONALs

OGP1:

```
{ ?album dbpedia-owl:artist ?artist .
  OPTIONAL { ?album dbpedia-owl:runtime ?runtime . }
  OPTIONAL { ?album foaf:img ?img . }
```

T1 dbpedia:Good_Day_Sunshine dbpedia-owl:runtime 1000.000

T2	**dbpedia:Help!_(album) dbpedia-owl:runtime 1723.000 .**
T3	dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles .
T4	**dbpedia:Rain_Dogs dbpedia-owl:artist dbpedia:Tom_Waits**
T5	dbpedia:Rain_Dogs foaf:img http://upload.wikimedia.org/wikipedia/commons/4/46TomWaitsRainDogs.jpg .
T6	**dbpedia:Bone_Machine dbpedia-owl:artist dbpedia:Tom_Waits**

Mapping	?album	?artist	?runtime	?img
μ_1	dbpedia:Help!_(album)	dbpedia:The_Beatles	1723.000	
μ_2	dbpedia:Rain_Dogs	dbpedia:Tom_Waits		http://upload.wikimedia.org/wikipedia/commons/4/46TomWaitsRainDogs.jpg .
μ_3	dbpedia:Bone_Machine	dbpedia:Tom_Waits		

Combining UNION and OPTIONAL

- What does the following mean?

```
{ ?album dbpedia-owl:releaseDate “01-01-1960” .
  { ?album dbpedia-owl:artist ?artist. } UNION
  { ?album dbpedia-ont:leadSinger ?artist. } OPTIONAL
  { ?artist foaf:name ?name . }
}
```

1. UNION of two patterns with an OPTIONAL condition
2. UNION of two patterns where the 2nd has an OPTIONAL condition

Solution (1):

```
{ ?album dbpedia-owl:releaseDate “01-01-1960” .
 { { ?album dbpedia-owl:artist ?artist. } UNION
   { ?album dbpedia-ont:leadSinger ?artist. } }
   OPTIONAL
    { ?artist foaf:name ?name . }
}
```

Combining UNION and OPTIONAL

General Rules:

1. OPTIONAL refers exactly to one grouped pattern to the right
2. OPTIONAL and UNION refer to all expressions to their left since both operators are left associative
3. UNION and OPTIONAL have the same precedence

```
{{s1 p1 o1} UNION {s2 p2 o1} OPTIONAL {s3 p3 o3}}
```

Equivalent to

```
{{s1 p1 o1} UNION {s2 p2 o1}} OPTIONAL {s3 p3 o3}
```

Combining UNION and Conjunction

```
{{s1 p1 o1} UNION {s2 p2 o1} {s3 p3 o3}}
```

Equivalent to

```
{{{s1 p1 o1} UNION {s2 p2 o1}} {s3 p3 o3}}
```

SPARQL Query Components: PROLOGUE

```
@prefix dbpedia: <http://dbpedia.org/resource/>
@prefix foaf: <http://xmlns.com/foaf/0.1/>
@prefix dppedia-owl: <http://dbpedia.org/resource/>

SELECT ?artist, ?genre
FROM <http://dbpedia.org>
WHERE { dbpedia:Help!_(album) dbpedia-owl:artist ?artist.
        ?artist dbpedia-owl:genre ?genre .
        ?artist foaf:name ?name }
ORDER BY ?name
```

- **PREFIX**
  - Definition of prefix labels for URIs
  - Syntax: Subtly different from Turtle syntax – no period (".") character used as separator

SPARQL Query Components: QUERY FORMS

```
@prefix dbpedia: <http://dbpedia.org/resource/>
@prefix foaf: <http://xmlns.com/foaf/0.1/>
@prefix dppedia-owl: <http://dbpedia.org/resource/>

SELECT ?artist, ?genre
FROM <http://dbpedia.org>
WHERE { dbpedia:Help!_(album) dbpedia-owl:artist ?artist.
        ?artist dbpedia-owl:genre ?genre .
        ?artist foaf:name ?name }
ORDER BY ?name
```

- **Query Forms**
  - **SELECT, ASK, DESCRIBE, CONSTRUCT**
    (to explain in detail later)

SPARQL Query Components: DATASET SPECIFICATION

```
@prefix dbpedia: <http://dbpedia.org/resource/>
@prefix foaf: <http://xmlns.com/foaf/0.1/>
@prefix dppedia-owl: <http://dbpedia.org/resource/>

SELECT ?artist, ?genre
FROM <http://dbpedia.org>
WHERE { dbpedia:Help!_(album) dbpedia-owl:artist ?artist.
        ?artist dbpedia-owl:genre ?genre .
        ?artist foaf:name ?name }
ORDER BY ?name
```

- **FROM** or **FROM NAMED**
  - *Optional clause*
  - Specify the data sources against which the queries will be evaluated
  - One default graph (**FROM** clause)
  - Zero or more named graphs (**FROM NAMED** clause)

SPARQL Query Components: QUERY PATTERN

```
@prefix dbpedia: <http://dbpedia.org/resource/>
@prefix foaf: <http://xmlns.com/foaf/0.1/>
@prefix dppedia-owl: <http://dbpedia.org/resource/>

SELECT ?artist, ?genre
FROM <http://dbpedia.org>
WHERE { dbpedia:Help!_(album) dbpedia-owl:artist ?artist.
        ?artist dbpedia-owl:genre ?genre .
        ?artist foaf:name ?name }
ORDER BY ?name
```

- **WHERE**
  - Defines the *patterns* to match against the data
  - Computation of the mappings/bindings

SPARQL Query Components: SOLUTION MODIFIERs

```
@prefix dbpedia: http://dbpedia.org/resource/
@prefix dbpprop: http://dbpedia.org/property

SELECT ?artist, ?genre
FROM <http://dbpedia.org>
WHERE { dbpedia:Help!_(album) dbpedia-owl:artist ?artist.
        ?artist dbpedia-owl:genre ?genre .
        ?artist foaf:name ?name }
ORDER BY ?name
```

- Solution Modifiers are *used to modify the result set*
  - ORDER BY, LIMIT, OFFSET *to reorganize the results*
  - GROUP BY *to combine the results*
  - DISTINCT *to eliminate duplicates*

SPARQL Query Forms

SPARQL supports different query forms:

- **SELECT** returns *ordered multi-set of variable bindings*
- **ASK** checks *whether a graph pattern has at least one solution*; returns a *Boolean* value (true/false)
- **CONSTRUCT** *returns a new RDF graph* as specified by the graph template using the computed bindings from the query's **WHERE** clause
- **DESCRIBE** *returns the RDF graph* containing the RDF data about the requested resource

Query Form: SELECT (1)

- The variables in the SELECT clause are returned along with their values according to the computed bindings
- Similar to the SELECT clause in SQL queries
- "*" means all components should be returned

Return the artists that made album identified by URI `dbpedia:Help!_(album)` *and the artist's music kind*

```
SELECT ?artist, ?genre
WHERE
{  dbpedia:Help!_(album) dbpedia-owl:artist ?artist .
   ?artist dbpedia-owl:genre ?genre }
```

Query Form: SELECT (2)

Return the name of the albums and tracks of albums that "The Beatles" made.

```
@prefix dbpedia: <http://dbpedia.org/resource/>
@prefix dbpprop: <http://dbpedia.org/property/>

SELECT ?album_name, ?track_name
WHERE { ?album  dbpedia-owl:artist ?artist .
        ?artist dbpprop:name "The Beatles" .
        ?album  dbpprop:name ?album_name .
        ?album  dbpprop:title ?track .
        ?track  dbpprop:name ?track_name .}
```

Query Form: SELECT (3)

Return the name of the albums of "The Beatles" with runtimes between 5400 and 3600 seconds and the tracks of albums whose runtimes are more than 900 seconds.

```
@prefix dbpedia: <http://dbpedia.org/resource/>
@prefix dbpprop: <http://dbpedia.org/property/>

SELECT ?album_name, ?track_name
WHERE { ?album  dbpedia-owl:artist ?artist .
        ?artist dbpprop:name "The Beatles" .
        ?album  dbpprop:name ?album_name .
        ?album  dbpprop:title ?track .
        ?track  dbpprop:name ?track_name .
        FILTER (?album dbpedia-owl:runtime > 3600 &&
                ?album dbpedia-owl:runtime < 5400 &&
                ?track dbpedia-owl:runtime > 900 )}
```

Query Form: SELECT (4)
Elimination of Duplicates

Return the name of the albums of The Beatles that have at least two different tracks.

```
SELECT SOLUTION_MODIFIER ?name
WHERE {
  ?album  dbpedia-owl:artist ?artist .
  ?artist dbpprop:name "The Beatles" .
  ?album  dbpprop:name ?album_name .
  ?album  dbpprop:title ?track1 .
  ?album  dbpprop:title ?track2 .
  FILTER (?track1!=?track2)
}
```

RESULTS:

REDUCED

?album_name
"Revolver"
"Revolver"
"Revolver"
"Revolver"
"Sessions"
"Abbey Road"
"Abbey Road"

DISTINCT

?album_name
"Revolver"
"Sessions"
"Abbey Road"

AGGREGATES

- Aggregates specify expressions over *groups of solutions*
- Used when the result is computed over a *group of solutions rather than a single solution*
  - *example*: average value of a set of values a variable takes
- Aggregates defined in SPARQL 1.1 are `COUNT`, `SUM`, `MIN`, `MAX`, `AVG`, `GROUP_CONCAT`, and `SAMPLE`.
- Solutions are *grouped* using the `GROUP BY` clause
- *Pruning at group level* is performed with the `HAVING` clause

Query Form: SELECT (5) AGGREGATES

Return the number of albums that The Beatles have recorded.

```
SELECT count(?album) as ?albums
WHERE { ?album  dbpedia-owl:artist ?artist .
        ?artist dbpprop:name “The Beatles” . }
```

Return the number of tracks per album recorded by The Beatles

```
SELECT ?album (count(?track) as ?tracks)
WHERE { ?album  dbpedia-owl:artist ?artist .
        ?artist dbpprop:name “The Beatles” .
        ?album  dbpedia:title ?track
} GROUP BY ?album
```

Query Form: SELECT (6) AGGREGATES

Return the total duration of the albums recorded by The Beatles where the duration of all tracks per album is greater than 3600000 seconds

```
SELECT ?album (SUM(?track_duration) AS ?album_duration)
WHERE {
        ?album dbpedia-owl:artist ?artist .
        ?artist dbpprop:name “The Beatles” .
        ?album dbpedia:title ?track .
        ?track dbpedia-owl:duration ?track_duration .
} GROUP BY ?album
  HAVING (SUM(?track_duration) > 3600000))
```

Query Form: SELECT (7)
SOLUTION MODIFIERS

- `ORDER BY:` establishes the order of a solution sequence:
  - ASC (ascending) - default, DESC (descending)

Return the most recent albums of "The Beatles" with duration more than one hour . Return the albums with higher duration first.

```
SELECT ?album
WHERE
{?al dbpedia-owl:artist ?ar. ?ar dbpprop:name "The Beatles".
 ?al dbpedia-owl:releaseDate ?date.?al dbpedia-owl:runtime ?rt
 FILTER(?rt> 3600)}
 ORDER BY DESC(?date)
```

Query Form: SELECT (8) SOLUTION MODIFIERS

- `LIMIT:` specifies the number of solutions to be returned
  - It should always be preceded by the ORDER BY modifier

Return the 10 most recent albums made by "The Beatles" that last more than one hour.

```
SELECT ?album
WHERE
{  ?album dbpedia-owl:artist ?artist .
   ?artist dbpprop:name "The Beatles".
   ?album dbpedia-owl:releaseDate ?date .
   ?album dbpedia-owl:runtime ?runtime
   FILTER(?runtime > 3600)}
   ORDER BY DESC(?date)
   LIMIT 10
```

Query Form: SELECT (9) SOLUTION MODIFIERS

- `OFFSET:` causes the solutions generated to start after the specified number of solutions
  - index of the first reported item in the sequence

Return the 5 most recent albums made by "The Beatles" with duration higher than one hour, starting from the tenth most recent album

```
SELECT ?album
WHERE
{  ?album dbpedia-owl:artist ?artist .
   ?artist dbpprop:name "The Beatles".
   ?album dbpedia-owl:releaseDate ?date .
   ?album dbpedia-owl:runtime ?rt . FILTER(?rt > 3600)}
   ORDER BY DESC(?date)
   LIMIT 5
   OFFSET 10
```

Query Form: DESCRIBE

- Takes as input a resource and returns the RDF graph containing information about the resource
- A resource is identified
  1. Through ***explicit IRIs***
  2. Through ***bindings of variables*** in the WHERE clause

Return all information about "The Beatles"

(1)

```
DESCRIBE dbpedia:The_Beatles
```

(2)

```
DESCRIBE ?group
WHERE {
        ?group rdf:type dbpedia:agent .
        ?group dbpedia:name "The_Beatles" . }
```

Possibly different results

Query Form: ASK

- Takes as input a graph pattern and returns *true if there exist at least one solution* and false otherwise.

Is Paul McCartney a member of "The Beatles"?

```
ASK
WHERE
    {?artist foaf:name "Paul Mc Cartney" .
     ?artist dbpedia-owl:associatedBand ?group .
     ?group  dbpprop:name "The Beatles" . }
```

Is Elvis Presley a member of 'The Beatles'?

```
ASK
WHERE
   {?artist foaf:name "Elvis Presley" .
    ?artist dbpedia-owl:associatedBand dbpedia:The_Beatles }.
```

Query Form: Construct

```
CONSTRUCT GP1
WHERE { GP2 }
……
```

- Returns ***a new graph*** specified by *an optional* ***pattern***
- If the pattern is missing, then the graph pattern in the **WHERE** ***clause*** is considered
- Pattern uses ***variables*** from the query's **WHERE** ***clause***
- Graph is obtained *from the variable bindings* in the query's **WHERE** clause

Query Form: Construct (1)

Return a graph containing all the information about "The Beatles" except type information

```
CONSTRUCT
WHERE {dbpedia:The_Beatles ?property ?object.
       FILTER(?property!=rdf:type)}
```

RDF Triples

T1	dbpedia:The_Beatles rdf:type dbpedia-owl:Organisation .
T2	**dbpedia:The_Beatles rdf:type dbpedia-owl:Band .**
T3	dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Pop_music .
T4	**dbpedia:The_Beatles dbpedia-owl:hometown dbpedia:Liverpool .**
T5	dbpedia:The_Beatles dbprop:name "The Beatles" .

Result:

C1	dbpedia:The_Beatles dbpedia-owl:genre dbpedia:Pop_music .
C2	dbpedia:The_Beatles dbpedia-owl:hometown dbpedia:Liverpool .
C3	dbpedia:The_Beatles dbprop:name "The Beatles"

Query Form: Construct (2)

```
CONSTRUCT {?track dc:creator ?artist_name}
WHERE { ?album dbpedia-owl:artist ?artist.
?album dbpprop:title ?track. ?artist dbpprop:name ?artist_name .}
```

RDF Triples

T1	dbpedia:Help!_(album) dbpprop:title dbpedia:Yesterday .
T2	**dbpedia:Help!_(album) dbpprop:title dbpedia-owl:Help!_(song) .**
T3	dbpedia:Let_It_Be dbpprop:title dbpedia:Dig_A_Pony .
T4	**dbpedia:Let_It_Be dbpprop:title dbpedia:Let_It_Be_(song) .**
T5	dbpedia:The_Beatles dbprop:name "The Beatles" .
T6	**dbpedia:Help!_(album) dbpedia-owl:artist dbpedia:The_Beatles**
T7	dbpedia:Let_It_Be dbpedia-owl:artist dbpedia:The_Beatles

Result:

C1	dbpedia:Yesterday dc:creator "The Beatles" .
C2	**dbpedia-owl:Help!_(song) dc:creator "The Beatles" .**
C3	dbpedia:Dig_A_Pony dc:creator "The Beatles" .
C4	**dbpedia:Let_It_Be_(song) dc:creator "The Beatles" .**

Matching RDF Literals

- ***Language Tags***
  - "Athens"@en
  - "Αθήνα"@gr
  - "Atene"@it
- Queries Q1, Q2 have different results

- ***Typed Literals***

1 = "1"^^xsd:integer

1.5 = "1.5"^^xsd:decimal

1.0E6 = "1"^^xsd:double

true = "true"^^xsd:boolean

```
Q1: SELECT ?v WHERE {?v ?p "Athens"@en}
Q2: SELECT ?v WHERE {?v ?p "Atene"@it}
```

- The @en language tag means that the string is an English word and will match differently than any other language tag (similarly for the other language tags).

Assigning Variables

- The *value of an expression* can be added to a solution mapping by *binding a new variable* (which can be further used and returned)

Calculate the duration of the tracks from ms to s, and store the value using the dbpedia-ont:runtime property .

```
CONSTRUCT { ?track dbpedia-ont:runtime ?secs .}
WHERE {
  dbpedia:The_Beatles foaf:made ?album .
  ?album mo:track ?track .
  ?track mo:duration ?duration .
  BIND((?duration/1000) AS ?secs) .
}
```

Sub-queries & Aggregate Values

- To combine the CONSTRUCT query form with aggregate values, a sub-query should be created inside the WHERE clause

Materialize the duration of the albums recorded by 'The Beatles'.

```
CONSTRUCT {?album music-ont:duration ?album_duration .}
WHERE {
  SELECT ?album (SUM(?track_duration) AS ?album_duration)
{
  dbpedia:The_Beatles foaf:made ?album .
  ?album mo:track ?track .
  ?track mo:duration ?track_duration .
  } GROUP BY ?album
    HAVING (SUM(?track_duration) > 3600000)}
```

UPDATING LINKED DATA WITH SPARQL 1.1

Data Management

SPARQL 1.1 provides data update operations:

- **INSERT data:** adds some triples, given inline in the request, into a graph 

- **DELETE data:** removes some triples, given inline in the request, if the respective graphs contains those 

- **DELETE/INSERT data:** uses in parallel INSERT and DELETE

Data Management

- **INSERT**

Insert *the following triples into the graph <http://musicbrainz.org/20130302>*

```
INSERT DATA { GRAPH { <http://musicbrainz.org/20130302>
   <http://musicbrainz.org/artist/a1> foaf:made
     <http://musicbrainz.org/release/r1> ,
     <http://musicbrainz.org/release/r2> .

    <http://musicbrainz.org/release/r1> dc:title  “r1’s
title” .
     <http://musicbrainz.org/release/r2> dc:title  “r2’s
title” } }
```

Data Management

- **DELETE**

Delete *all the information about the album "Casualties" of "The Beatles."*

```
DELETE { ?album ?predicate ?object . }
WHERE {
        ?album dbpedia-owl:artist dbpedia:The_Beatles .
        ?album dbpprop:name "Casualities".
        ?album ?predicate ?object . }
```

Data Management

- **DELETE/INSERT data**

Delete *the status of "Peter Best" as current member of "The Beatles", and* ***insert*** *his status as former member of the band in graph* <http://musicbrainz.org/20130302>

```
DELETE { dbpedia:The_Beatles db-ont:currentMember ?x . }

INSERT { GRAPH <http://musicbrainz.org/20130302>
       { dbpedia:The_Beatles dbpedia-owl:pastMembers ?x .} }
WHERE  {
        dbpedia:The_Beatles db-ont:currentMember ?member .
        ?member foaf:name "Peter Best" .}
```

Graph Management

SPARQL 1.1 provides graph update operations:

- **CREATE:** creates an empty graph in the Graph Store
- **LOAD:** reads the content of a document into a graph in the Graph Store
- **CLEAR:** removes all triples in one or more graphs
- **DROP:** removes the graph from the Graph Store
- **Other operations:** `COPY, MOVE, ADD`

Graph Management (2)

CREATE

- Creates a new ***named graph***

```
CREATE GRAPH <http://musicbrainz.org/20130302>
```

LOAD

- An RDF graph can be loaded **from a URL**

```
LOAD <http://xmlns.com/foaf/spec/20100809.rdf>
```

```
LOAD <http://xmlns.com/foaf/spec/20100809.rdf>
INTO <http://xmlns.com/foaf/0.1/>
```

Named graph

Graph Management (3)

CLEAR

- Removes all triples in the graph (it is emptied but not deleted!)
- The graph(s) can be specified with the following keywords: `DEFAULT, NAMED, ALL, GRAPH`

```
CLEAR GRAPH <http://musicbrainz.org/20130302>
```

DROP

- The given graph is removed from the Graph Store, including its content
- Can be used with the **DEFAULT** and **ALL** keywords

```
DROP GRAPH <http://musicbrainz.org/20130302>
```

Graph Management (4)

SPARQL 1.1 provides other graph management operations:

- **COPY … TO …**

```
COPY GRAPH <http://musicbrainz.org/20130302>
TO GRAPH <http://musicbrainz.org/20130303>
```

- **MOVE … TO …**

```
MOVE GRAPH <http://musicbrainz.org/temp>
TO GRAPH <http://musicbrainz.org/20130303>
```

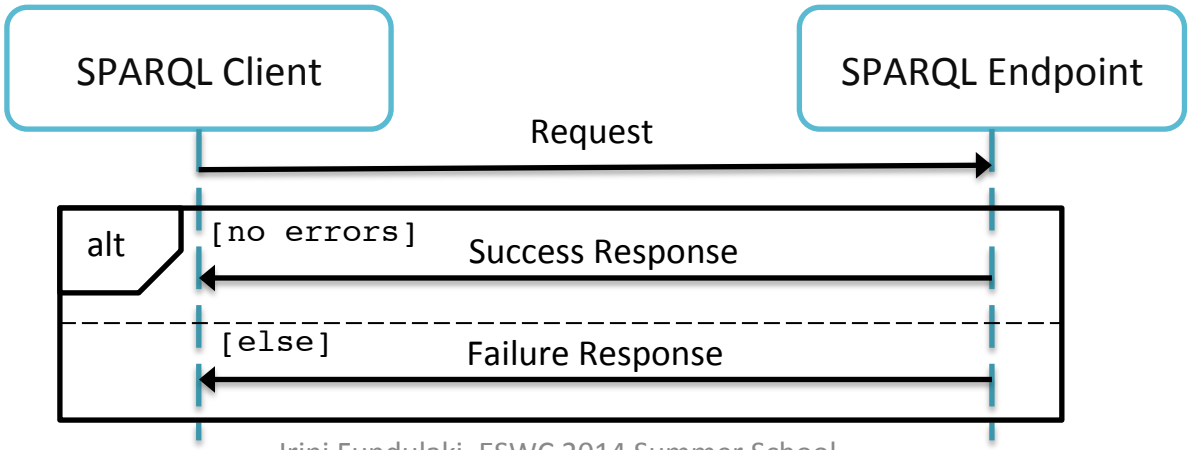
- **ADD … TO …**

```
ADD GRAPH <http://musicbrainz.org/20130302>
TO GRAPH <http://musicbrainz.org/20130303>
```

SPARQL PROTOCOL FOR RDF

SPARQL 1.1. Protocol

- Consists of two **operations**: query and update
- An operation defines:
  - The HTTP method (GET or POST)
  - The HTTP query string parameters
  - The message content included in the HTTP request body
  - The message content included in the HTTP response body



Query Operation

- **Sends a SPARQL query** to a service and **receives the results** of the query
- The response is:
  - XML, JSON, CSV/TSV from a **SELECT** query
  - RDF/XML, Turtle from a **CONSTRUCT** query
- May be invoked using **HTTP GET** or **HTTP POST**. The method POST with URL encoding is mostly used when the query string is too long

Query Operation (2)

SPARQL Query:

```
PREFIX dbpedia: <http://dbpedia.org/resource/>
PREFIX dbpedia-ont: <http://dbpedia.org/ontology/>
SELECT ?album
WHERE { ?album dbpedia-owl:artist dbpedia:The_Beatles .}
LIMIT 3
```

HTTP GET request:

```
GET /sparql?default-graph-uri=http%3A%2F%2Fdbpedia.org&query=PREFIX+dbpedia%3A+%3Chttp
%3A%2F%2Fdbpedia.org%2Fresource%2F%3E%0D%0APREFIX+dbpedia-ont%3A+%3Chttp%3A%2F%2Fdbped
ia.org%2Fontology%2F%3E%0D%0ASELECT+%3Falbum+%0D%0AWHERE+%7B+%3Falbum+dbpedia-ont%3Aar
tist+dbpedia%3AThe_Beatles+.%7D+%0D%0ALIMIT+3%0D%0A&format=application%2Fsparql-result
s%2Bxml&timeout=0&debug=on HTTP/1.1
Host: dbpedia.org
```

Try this query!

(Click on the hurl icon)

Update Operation

- **Sends a SPARQL update** request to a service
- Should be invoked using the **HTTP PATCH/POST** method
- The response consists of a HTTP response status code, which indicates success or failure of the operation

Acknowledgements

- ***Content from***
  - Knowledge Technologies Course, University of Athens, Greece
    - Available at http://cgi.di.uoa.gr/~pms509/2012-2013/lectures/SPARQL%20-%20lecture%201.pdf
  - ESWC Summer School 2013 Slideshare
  - SPARQL, Martin Svoboda
    - Available at : http://www.ksi.mff.cuni.cz/~svoboda/teaching/2011-S1-NSWI144/seminar/05-sparql-1.pdf
  - W3C Candidate Recommendation "SPARQL Query Language for RDF"
    - Available at: *http://www.w3.org/TR/rdf-sparql-query/*
- Part of this work has been done with the support of *Linked Data Benchmark Council Project (FP7- 317548)*