TECHNISCHE UNIVERSITÄT DRESDEN

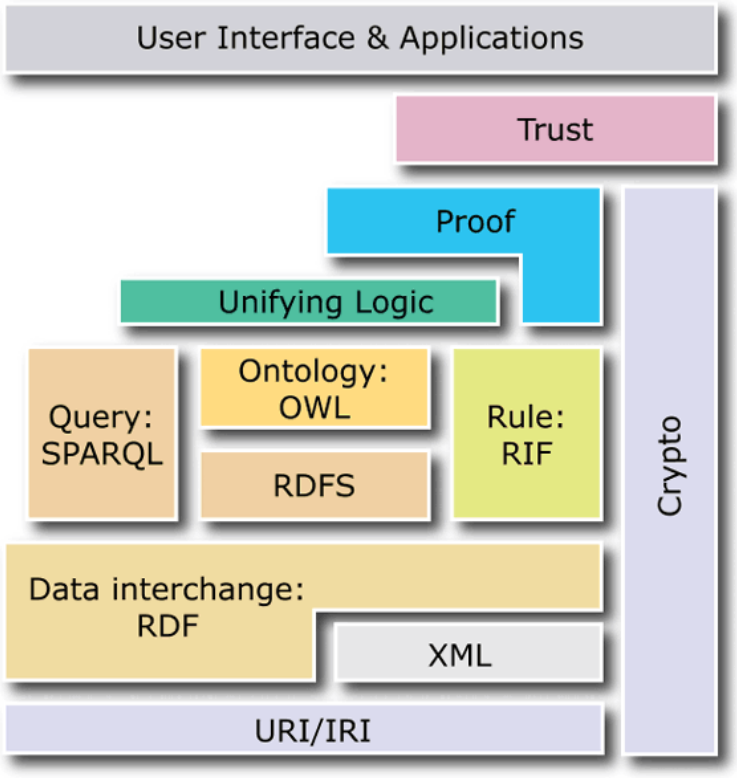
FOUNDATIONS OF SEMANTIC WEB TECHNOLOGIES

SPARQL 1.1

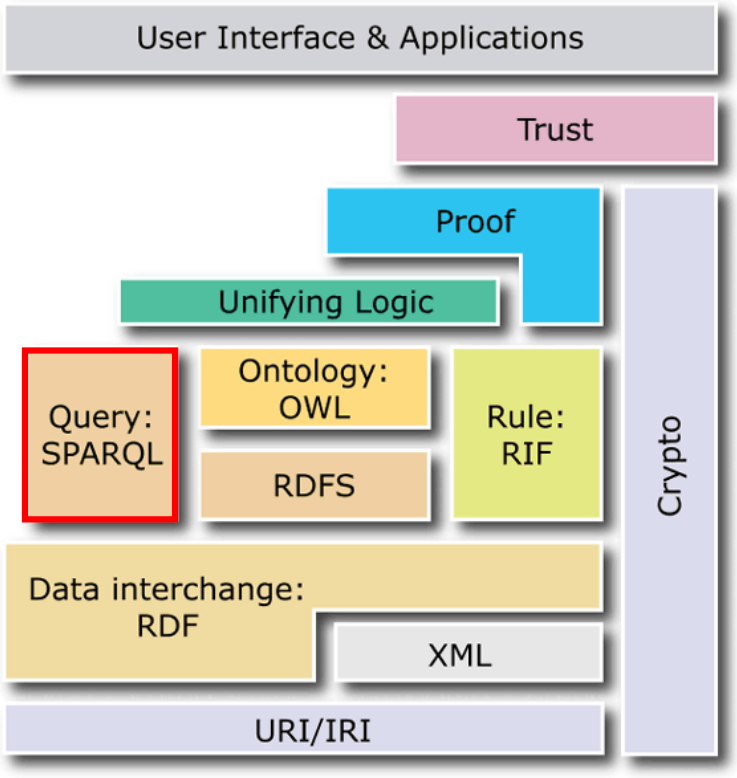
Sebastian Rudolph

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

The SPARQL Query Language



The SPARQL Query Language



Agenda

1. Recap
2. SPARQL 1.1 Query Extensions
   - Expressions in Selection and Bindings
   - Aggregates
   - Subqueries
   - Property Paths
   - Negation
3. SPARQL Protocol
4. SPARQL Update
5. SPARQL Service Descriptions
6. Summary

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Example Pattern

Example

```
{ ?book ex:price ?price
  FILTER (?price < 15)
  OPTIONAL { ?book ex:title ?title }
  { ?book ex:author ex:Shakespeare } UNION
  { ?book ex:author ex:Marlowe } }
```

Translation into SPARQL Algebra

```
Filter(?price < 15,
      Join(
       LeftJoin(Join(Z,
           Bgp(?book <http://eg.org/price> ?price)),
               Bgp(?book <http://eg.org/title> ?title),
               true),
       Union(Bgp(?book <http://eg.org/author>
                       <http://eg.org/Shakespeare>),
             Bgp(?book <http://eg.org/author>
                       <http://eg.org/Marlowe>))))
```

Simplification of the SPARQL Algebra

```
Filter(?price < 15,
    Join(
      LeftJoin(Bgp(?book <http://eg.org/price> ?price),
               Bgp(?book <http://eg.org/title> ?title),
               true),
      Union(Bgp(?book <http://eg.org/author>
                      <http://eg.org/Shakespeare>),
            Bgp(?book <http://eg.org/author>
                      <http://eg.org/Marlowe>))))
```

Semantics of the SPARQL Algebra Operators

Bgp(P)	match/evaluate pattern P
Join(M_1, M_2)	conjunctive join of solutions M_1 and M_2
Union(M_1, M_2)	union of solutions M_1 with M_2
LeftJoin(M_1, M_2, F)	optional join of M_1 with M_2 with filter constraint F (`true` if no filter given)
Filter(F, M)	filter solutions M with constraint F
Z	empty pattern (identity for join)

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Expressions in the Selection and Bindings

Solutions can be extended by evaluated expressions with `(expression AS ?var)` used for the assignment:

- In the `SELECT` clause
- In the `GROUP BY` clause
- Within `BIND` in a group graph pattern

Solutions from a group can further be joined with solutions given via `VALUES`

Example BIND (without Prefix Declarations)

Data

```
ex:Book ex:title "SPARQL Tutorial" ; ex:price 42 ; ex:discount
10 .
```

Query

```
SELECT ?title ?price WHERE
{ ?b ex:title ?title; ex:price ?p ; ex:discount ?r
 BIND ((?p-?r) AS ?price) }
```

Result

$?title \mapsto$ "SPARQL Tutorial", $?price \mapsto 32$

$\rightsquigarrow$ Algebra: Extend(Bgp(...), ?price, (?p-?r))

Example SELECT Expressions (without Prefix Declarations)

Data

```
ex:Book ex:title "SPARQL Tutorial" ; ex:price 42 ; ex:discount
10 .
```

Query

```
SELECT ?title ((?p-?r) AS ?price) WHERE
{ ?b ex:title ?title; ex:price ?p ; ex:discount ?r }
```

Result

$?title \mapsto$ "SPARQL Tutorial", $?price \mapsto 32$

$\rightsquigarrow$ Algebra: Extend(Bgp(...), ?price, (?p-?r))

Example VALUES

Data

```
ex:Book1 ex:title "SPARQL Tutorial".
ex:Book2 ex:title "SemWeb".
```

Query

```
SELECT ?title WHERE {
  ?b ex:title ?title
  VALUES ?b { ex:Book1 }
}
```

Result

$?title \mapsto$ "SPARQL Tutorial"

$\rightsquigarrow$ Bindings are conjunctively joined

Aggregates

- Aggregates allow for grouping of solutions and the computation of values over the groups

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Example

```
SELECT     (COUNT(?student) AS ?c) ?lecture
WHERE      { ?student ex:attends ?lecture }
GROUP BY   ?lecture
HAVING     ?c > 5
```

Aggregates

- Aggregates allow for grouping of solutions and the computation of values over the groups

Example

```
SELECT     (COUNT(?student) AS ?c) ?lecture
WHERE      { ?student ex:attends ?lecture }
GROUP BY   ?lecture
HAVING     ?c > 5
```

- `GROUP BY` groups the solutions (here into students who attend the same lecture)
- `COUNT` is an aggregate function that counts the solutions within a group (here the number of students in the lecture)
- `HAVING` filters aggregated values

Aggregates in SPARQL 1.1

SPARQL 1.1 supports the following aggregate functions, which are evaluated over the values in a group:

- `COUNT` – counts the solutions
- `MIN` – finds the minimal value
- `MAX` – finds the maximal value
- `SUM` – sums up the values
- `AVG` – computes the average
- `GROUP_CONCAT` – string concatenation, Example: `GROUP_CONCAT(?x ; separator=", ")`
- `SAMPLE` – picks a random value

Exercise Aggregates

Data

```
ex:Paul ex:hasMark 2.0 .
ex:Paul ex:hasMark 3.0 .
ex:Mary ex:hasMark 2.0 .
ex:Peter ex:hasMark 3.5 .
```

Query

```
SELECT ?student (AVG(?note) as ?avg)
WHERE { ?student ex:hasMark ?note }
GROUP BY ?student
HAVING (?avg > 2.0)
```

Solution Aggregates

Solution Aggregates

student	avg
ex:Paul	2.5
ex:Peter	3.5

Subqueries

Query

```
SELECT ?name WHERE {
  ?x foaf:name ?name .
  { SELECT ?x (COUNT(*) AS ?count)
    WHERE { ?x foaf:knows ?y . }
    GROUP BY ?x
    HAVING (?count = 3)
  }
}
```

- Results for the inner query are conjunctively joined with the results of the outer query

Regular Expressions in Patterns

Property Paths are constructed using regular expressions over predicates

- Paths with arbitrary length: `?s ex:p+ ?o`, `?s ex:p* ?o`
- Alternative paths: `?s` (`ex:`p_1|`ex:`p_2) `?o`
- Negation of paths: `?s !ex:p ?o`
- Inverse paths: `?s ^ex:p ?o` same as `?o ex:p ?s`
- Sequence of paths: `?s ex:`p_1 / `ex:`p_2 `?o`
- Length zero or one path: `?s ex:p? ?o`

Regular Expressions in Patterns

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- Property paths are, where possible, translated into standard SPARQL constructs
- Some new operators are still necessary

Property Path Example

Query 1

```
PREFIX ...
SELECT ?xName WHERE {
  ?x rdf:type foaf:Person .
  ?x foaf:name ?xName
  ?x foaf:knows/foaf:knows/foaf:name "Bill Gates" .
}
```

Query 2

```
PREFIX ...
SELECT ?s WHERE {
  ?s  rdf:type  ?type .
  ?type rdfs:subClassOf* ex:SomeClass .
}
```

Negation in Queries

- Two forms of negation with conceptual and small semantic differences
  1. Test non-matches for a pattern
  2. Removal of matching patterns

1. Filter

```
SELECT ?x WHERE {
  ?x rdf:type foaf:Person .
  FILTER NOT EXISTS { ?x foaf:name ?name }
}
```

2. Minus

```
SELECT ?x WHERE {
  ?x rdf:type foaf:Person .
  MINUS { ?x foaf:name ?name }
}
```

Evaluation of Negation via Filter

Data

```
_:x rdf:type foaf:Person .
_:x foaf:name "Peter" .
_:y rdf:type foaf:Person .
```

Query Pattern

```
{ ?x rdf:type foaf:Person .
  FILTER NOT EXISTS { ?x foaf:name ?name } }
```

1. $[\![\text{Bgp}(\text{1. Pattern})]\!]_G$: μ_1 : ?x $\mapsto$ _:x, μ_2 : ?x $\mapsto$ _:y
2. For each solution, we instantiate the second pattern
   - Solution is removed if the instantiated pattern matches (μ_1)
   - otherwise we keep the solution (μ_2)

Evaluation of Negation via Minus

Data

```
_:x rdf:type foaf:Person .
_:x foaf:name "Peter" .
_:y rdf:type foaf:Person .
```

Query Pattern

```
{ ?x rdf:type foaf:Person .
  MINUS { ?x foaf:name ?name } }
```

$[\![\text{Bgp(1. Pattern)}]\!]_G$: $\Omega_1 = \{\mu_1 : \texttt{?x} \mapsto \texttt{\_:x}, \mu_2 : \texttt{?x} \mapsto \texttt{\_:y}\}$

$[\![\text{Bgp(2. Pattern)}]\!]_G$: $\Omega_2 = \{\mu_3 : \texttt{?x} \mapsto \texttt{\_:x}, \texttt{?name} \mapsto \texttt{"Peter"}\}$

$[\![\text{Minus}(\Omega_1, \Omega_2)]\!]_G$: $\Omega = \{\mu \mid \mu \in \Omega_1 \text{ and } \forall \mu' \in \Omega_2 : \mu \text{ and } \mu' \text{ incompatible or } \text{dom}(\mu) \cap \text{dom}(\mu') = \emptyset\}$

$\mu_1 \notin \Omega$: μ_1 compatible with μ_3 and non-disjoint domains

$\mu_2 \in \Omega$: μ_2 incompatible with μ_3

Differences Minus and Filter Negation

Data

```
ex:a ex:b ex:c .
```

Query Pattern

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

- Filter pattern matches always (variables disjoint) $\rightsquigarrow$ every solution is removed

Query Pattern

```
{ ?s ?p ?o MINUS { ?x ?y ?z } }
```

- Minus does not remove any solutions since the domain of the solutions is disjoint

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SPARQL Protocol

- Specifies how queries can be sent to a SPARQL endpoint in the Web and how results are returned
- Specifies how errors are communicated
- Query
  - `GET` Query etc. is part of the URL: `http://server/endpoint1?query=...`
  - `POST` Query is in the body of the HTTP request, e.g., via an HTML form
- Update
  - `http://server/endpoint2?update=...`
  - `POST` with content-type application/sparql-update
  - `POST` via HTML form
- Query and Update are separate services

Graph Store HTTP Protocol

- Application protocol for distributed updating and fetching of RDF graph content via HTTP
  - IRIs identify a graph in a graph store
  - `GET` to receive the graph content
  - `PUT` to send a query that modifies a graph
  - `DELETE` to delete a graph
  - `POST` to merge submitted RDF data into an existing graph

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SPARQL Update

- For manipulation of graphs or graph content
- Based on the idea of a graph store (Quads)
  - Addition and removal of graphs
  - Addition and removal of triples in a graphs
- `LOAD`, `DROP`, `CREATE`
- `INSERT`, `DELETE` for data/triples
- No transactions, a query can consist of several atomic parts

Example Query

```
DELETE { ?person foaf:givenName "Bill" }
INSERT { ?person foaf:givenName "William" }
WHERE {
  ?person a foaf:Person .
  ?person foaf:givenName "Bill"
}
```

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Service Descriptions

- Method and vocabulary for describing SPARQL endpoints
- Client/User can request information about the SPARQL service, e.g.,
  - supported extension functions,
  - used data set or
  - supported inference mechanisms

HTTP Request

```
GET /sparql/ HTTP/1.1
Host: www.example.org
Accept: text/turtle
```

Possible Response (beginning)

```
HTTP/1.1 200 OK
Date: Fri, 09 Oct 2009 17:31:12 GMT
Server: Apache/1.3.29 (Unix) PHP/4.3.4 DAV/1.0.3
Connection: close
Content-Type: text/turtle

@prefix sd:
<http://www.w3.org/ns/sparql-service-description#> .
@prefix ent: <http://www.w3.org/ns/entailment/> .
@prefix prof: <http://www.w3.org/ns/owl-profile/> .
...
```

Possible Response (continued)

```
<http://ex.org/Distance> a sd:Function .

[] a sd:Service ;
  sd:endpoint <http://ex.org/sparql/> ;
  sd:supportedLanguage sd:SPARQL11Query ;
  sd:resultFormat
    <http://www.w3.org/ns/formats/RDF_XML>,
    <http://www.w3.org/ns/formats/Turtle> ;
  sd:extensionFunction <http://ex.org/Distance> ;
  sd:feature sd:DereferencesURIs ;
  sd:defaultEntailmentRegime ent:RDFS ;
```

Possible Response (continued)

```
sd:defaultDatasetDescription [
    a sd:Dataset ;
    sd:defaultGraph [
      a sd:Graph ;
      void:triples 100
    ] ;
    sd:namedGraph [
      a sd:NamedGraph ;
      sd:name <http://ex.org/named-graph> ;
      sd:entailmentRegime ent:OWL-RDF-Based ;
      sd:supportedEntailmentProfile prof:RL ;
      sd:graph [
        a sd:Graph ;
        void:triples 2000
      ]
    ]
] .
```

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Summary

- We have learned about the main SPARQL 1.1 extensions
- SPARQL 1.1 is a recommendation since March 2013
- SPARQL UPDATE allows for modifying graphs
- Protocol specifies the client server communication
- Service Descriptions describe a SPARQL service (machine readable)
- Further result formats: JSON, CVS, TSV (not covered)

Outlook:

- Entailment Regimes: SPARQL with inferred results

Public SPARQL Endpoints

DBPedia structured Wikipedia Data (> 100 million triples):
`http://dbpedia.org/sparql`

DBTune 14 billion RDF triple about music
`http://dbtune.org/jamendo/store/user/query`

CKAN Dataset repository with SPARQL service
`http://semantic.ckan.net/`
`http://semantic.ckan.net/snorql/`

Linked Movie Database `http://data.linkedmdb.org/` and
`http://data.linkedmdb.org/sparql`

SPARQL Editor with examples about space data `http://api.talis.com/stores/space/items/tutorial/spared.html`

Semantic Web Dog Food Information about authors, publications and conferences `http://data.semanticweb.org/snorql`