UNIVERSITY OF JYVÄSKYLÄ

Lecture 2: Storing and querying RDF data

TIES4520 Semantic Technologies for Developers
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Khriyenko Oleksiy

Part 1

Storing RDF data

Storing of RDF

- Small datasets (few triples)
  - RDF file published on the web or stored locally
  - Examples: ***.rdf**, ***.nt**, ***.ttl**, ***.n3**, etc.
- Large datasets (thousands to millions of triples)
  - Database-bases solution better
  - Usually in form of RDF storage
- Legacy data
  - Keep in original form
  - Provide mapping to RDF
  - Expose as RDF to the outer world

Triplestore: *http://en.wikipedia.org/wiki/Triplestore*

Graph databases: *https://en.wikipedia.org/wiki/Graph_database*

List of triplestores: *http://www.w3.org/wiki/LargeTripleStores*

Native RDF Stores

RDF stores that implement their own database engine without reusing the storage and retrieval functionalities of other database management systems:

- ***AllegroGraph*** (commercial) is a commercial RDF graph database and application framework developed by Franz Inc. There are different editions of AllegroGraph and different clients: the free *RDFStore* server edition is limited to storing less than 50 million triples, a developer edition capable of storing a maximum of 600 million triples, and an enterprise edition with storage capacity only limited by the underlying server infrastructure (1+Trillion). Clients connectors are available for Java, Python, Lisp, Clojure, Ruby, Perl, C#, and Scala. Link: *https://allegrograph.com/allegrograph/*, *http://franz.com/agraph/allegrograph/*
- ***GraphDB™*** (formerly ***OWLIM***) – An Enterprise Triplestore with Meaning (GNU LGPL license and commercial) It is a family of commercial RDF storage solutions, provided by Ontotext. There are three different editions: *GraphDB™ Lite*, *GraphDB™ Standard* and *GraphDB™ Enterprise*. Link: *http://ontotext.com/products/graphdb/*
- ***Stardog*** is an enterprise data unification platform built on smart graph technology: query, search, inference, and data virtualization. Stardog is a pure Java RDF database which supports all of the OWL2 profiles using a dynamic (backward-chaining) approach. It also includes unique features such as Integrity Constraint Validation and explanations, i.e. proofs, for inferences and integrity constraint violations. It also integrates a full-text search index based on Lucene. Link: *http://stardog.com/*
- ***Apache Jena TDB*** (open-source) is a component of the Jena Semantic Web framework and available as open-source software released under the BSD license. Link: *http://jena.apache.org/*
- ***Mulgara*** (open source, Open Software License) is the community-driven successor of Kowari and is described as a purely Java-based, scalable, and transaction-safe RDF database for the storage and retrieval of RDF-based metadata. Link: *http://www.mulgara.org/*
- ***RDFox*** is a highly scalable in-memory RDF triple store that supports shared memory parallel datalog reasoning. It is a cross-platform software written in C++ that comes with a Java wrapper allowing for an easy integration with any Java-based solution. Link: *http://www.cs.ox.ac.uk/isg/tools/RDFox/*

DBMS-backed Stores

RDF Stores that use the storage and retrieval functionality provided by another database management system:

- ***Apache Jena SDB*** (open-source) is another component of the Jena Semantic Web framework and provides storage and query for RDF datasets using conventional relational databases: Microsoft SQL Server, Oracle 10g, IBM DB2, PostgreSQL, MySQL, HSQLDB, H2, and Apache Derby. Link: *http://jena.apache.org/*
- ***Oracle Spatial and Graph: RDF Semantic Graph*** (formerly ***Oracle Semantic Technologies***) is a W3C standards-based, full-featured graph store in Oracle Database for Linked Data and Social Networks applications.

  Link: *http://www.oracle.com/technetwork/database/options/spatialandgraph/overview/rdfsemantic-graph-1902016.html*
- ***Semantics Platform*** is a family of products for building medium and large scale semantics-based applications using the Microsoft .NET framework. It provides semantic technology for the storage, services and presentation layers of an application. Link: *http://www.intellidimension.com/products/semantics-platform/*
- ***ARC2*** is a free, open-source semantic web framework for PHP applications released under the W3C Software License and the GNU GPL. It is designed as a PHP library and includes RDF parsers (RDF/XML, N-Triples, Turtle, SPARQL + SPOG, Legacy XML, HTML tag soup, RSS 2.0, Google Social Graph API JSON…) and serializers (N-Triples, RDF/JSON, RDF/XML, Turtle, SPOG dumps…), an RDBMS-backed (MySQL) RDF storage, and implements the SPARQL query and update specifications. Active code development has been discontinued due to lack of funds and the inability to efficiently implement the ever-growing stack of RDF specifications. Link: *https://github.com/semsol/arc2/wiki*

  More reading: *http://tinman.cs.gsu.edu/~raj/8711/sp11/presentations/ARC_RDF_Store.pdf*

  EASYRDF A PHP library designed to make it easy to consume and produce RDF. Designed for use in mixed teams of experienced and inexperienced RDF developers. Written in PSR-2 compliant PHP and tested extensively using PHPUnit. Link: *http://www.easyrdf.org/*
- ***RDFLib*** is a pure Python package working with RDF that contains most things you need to work with, including: parsers and serializers for RDF/XML, N3, NTriples, N-Quads, Turtle, TriX, RDFa and Microdata; a Graph interface which can be backed by any one of a number of Store implementations; store implementations for in memory storage and persistent storage on top of the Berkeley DB; a SPARQL 1.1 implementation supporting Queries and Update statements. Link: *https://rdflib.readthedocs.org/en/latest/*

Non-RDF DB support

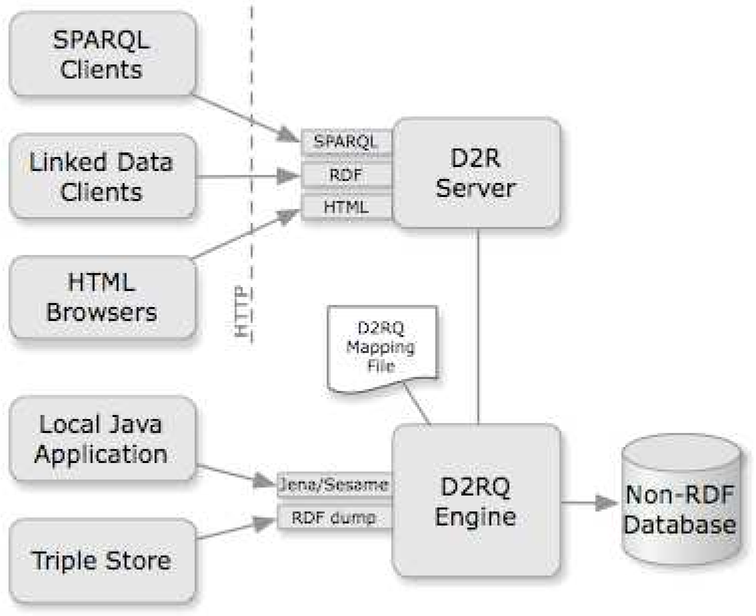
- ***D2RQ Platform*** is a system for accessing relational databases as virtual, read-only RDF graphs. It offers RDF-based access to the content of relational databases without having to replicate it into an RDF store. Using D2RQ you can: query a non-RDF database using SPARQL, access the content of the database as Linked Data over the Web, create custom dumps of the database in RDF formats for loading into an RDF store, access information in a non-RDF database using the Apache Jena API.

  Link: *http://d2rq.org/*

The D2RQ Platform consists of:

- **D2RQ Mapping Language**, a declarative mapping language for describing the relation between an ontology and an relational data model.
- **D2RQ Engine**, a plug-in for the Jena Semantic Web toolkit, which uses the mappings to rewrite Jena API calls to SQL queries against the database and passes query results up to the higher layers of the frameworks.
- **D2R Server**, an HTTP server that provides a Linked Data view, a HTML view for debugging and a SPARQL Protocol endpoint over the database.

Supported databases: Oracle, MySQL, PostgreSQL, SQL Server, HSQLDB, Interbase/Firebird



Hybrid Stores

RDF Stores that supports both architectural styles (native and DBMS-backed):

- ***RDF4J (Sesame)*** (open-source) is an open source framework for storage, inferencing and querying of RDF data. It is a library that is release under the Aduna BSD-style license and can be integrated in any Java application. Sesame includes RDF parsers and writers (Sesame Rio), a storage and inference layer (SAIL API) that abstracts from storage and inference details, a repository API for handling RDF data, and an HTTP Server for accessing Sesame repositories via HTTP. It operates in any Java-supporting environment and can be used by any Java application. Link: *http://rdf4j.org/*
- ***OpenLink Virtuoso Universal Server*** is a hybrid storage solution for a range of data models, including relational data, RDF and XML, and free text documents. Through it unified storage it can be also seen as a mapping solution between RDF and other data formats, therefore it can serve as an integration point for data from different, heterogeneous sources. Virtuoso has gained significant interest since it is used to host many important Linked Data sets (e.g., DBpedia), and preconfigured snapshots with several important Linked Data sets are offered. Virtuoso is offered as an open-source version; for commercial purposes several license models exist. Link: *http://virtuoso.openlinksw.com/*
- ***Blazegraph*** (former Bigdata)(open-source and commercial license) is ultra-scalable, high-performance graph database with support for the Blueprints and RDF/SPARQL APIs. Blazegraph is available in a range of versions that provide solutions to the challenge of scaling graphs. Blazegraph solutions range from millions to trillions of edges in the graph. Link: *https://www.blazegraph.com/product/*
- ***CumulusRDF*** is an RDF store on a cloud-based architecture. CumulusRDF provides a REST-based API with CRUD operations to manage RDF data. The current version uses Apache Cassandra as storage backend. Link: *https://github.com/cumulusrdf/cumulusrdf*
- ***RedStore*** is a lightweight RDF triplestore written in C using the Redland library. Link: *http://www.aelius.com/njh/redstore/*

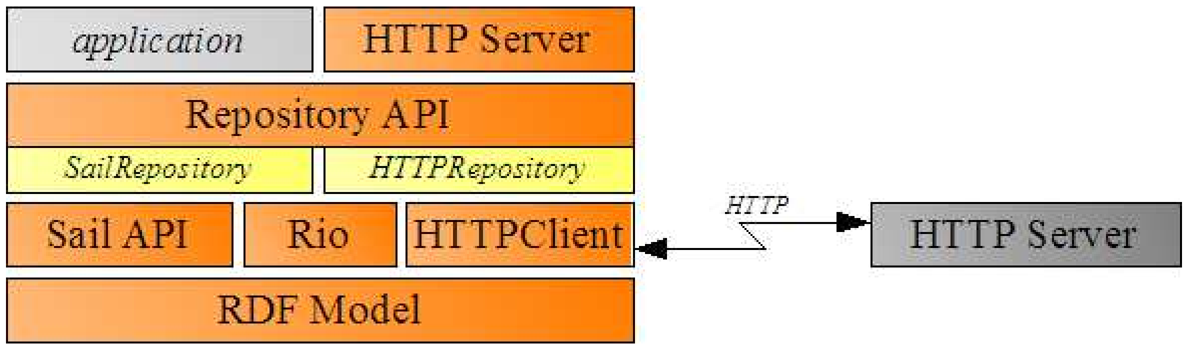
RDF4J

DRF4J (former ***Sesame)*** an open source Java framework for processing RDF data. Link: *http://rdf4j.org/*

- Features:
  - Parsing: Supports all major notations
  - Storing: In-memory, native store, file-based, and supports many third party storage solutions (*http://rdf4j.org/about/rdf4j-databases/*)
  - Inferencing: Ontology-based, custom Rule-based
  - Querying: SPARQL, SeRQL
- easy-to-use API that can be connected to all leading RDF storage solutions.

AliBaba is an RDF application library for developing complex RDF storage applications. It is a collection of modules that provide simplified RDF store abstractions to accelerate development and facilitate application maintenance. Link: *https://bitbucket.org/openrdf/alibaba*

RDF4J (Sesame) architecture



- Rio (RDF I/O)
  - Parsers and writers for various notations
- Sail (Storage And Inference Layer)
  - Low level System API
  - Abstraction for storage and inference
- Repository API
  - Higher level API
  - Developer-oriented methods for handling RDF data
- HTTP Server
  - Accessing Sesame through HTTP

Environmental variables

practical

- OS stores simple variables in its memory
- Applications can ask OS for the value
- Each variable has a name and a simple textual value
- To see variables and their values run (Win):
  - See all: `set`
  - See a concrete variable: `set VARNAME`
- Scope:
  - Global (valid for the whole OS)
  - Local (valid in the current command line window)
- To change or set new local variable run:

```
set VARNAME=some text here
```

Installing RDF4J workbench

- Simple web interface for storing and querying RDF data
- Install steps (no admin rights needed): practical
  1. Download and unzip newest RDF4J and Tomcat
  2. Copy all **`*.war`** files from RDF4Js **`war`** folder to Tomcat's **`webapps`** folder
  3. Start Tomcat
     - From bin folder by running **`startup.sh`** (UNIX) or **`startup.bat`** (Win)
     - You may need to set **`JAVA_HOME`** variable (it should point to JDK or JRE main folder)
  4. Go to *http://localhost:8080/rdf4j-workbench/*

More information: *http://docs.rdf4j.org/server-workbench-console/*

GraphDB

Otnotext GraphDB (formerly OWLIM) is a leading RDF Triplestore built on OWL (Ontology Web Language) standards. GraphDB handles massive loads, queries and OWL inferencing in real time. There are three different editions: *GraphDB Free*, *GraphDB Standard* and *GraphDB Enterprise*. Link: *http://ontotext.com/products/graphdb*/, *http://graphdb.ontotext.com/*

- Features:
  - Parsing: Supports all major notations
  - Storing: file-based native store
  - Inferencing: at load time, Ontology-based, custom Rule-based
  - Querying: SPARQL, supports HTTP based querying
- *GraphDB Server*: a set of programming interfaces that exposes all database functionality as a REST API.
- *GraphDB Workbench*: management interfaces implemented on top of the GraphDB Server REST API.
- Fully compliant with the RDF4J (Sesame) service API
- GraphDB on the Cloud: database as a service solution for small or medium database size and query load. (*https://cloud.ontotext.com/#/home*)
- Tools: *LoadRDF* tool: an OFFLINE tool, designed for fast loading of large data sets. (*http://graphdb.ontotext.com/documentation/free/loadrdf-tool.html*)

  Storage tool: an application for scanning and repairing a GraphDB repository. (*http://graphdb.ontotext.com/documentation/free/storage-tool.html*)

Installing GraphDB

- Installation options:
  - Run GraphDB as a desktop installation (only for GraphDB Free users)
  - Run GraphDB as a stand-alone server
  - Run GraphDB as a docker container

- *GraphDBFree* installation: **practical**
  1. Download installation file and run it (*https://ontotext.com/products/graphdb/*)
  2. Access workbench via *http://localhost:7200/*

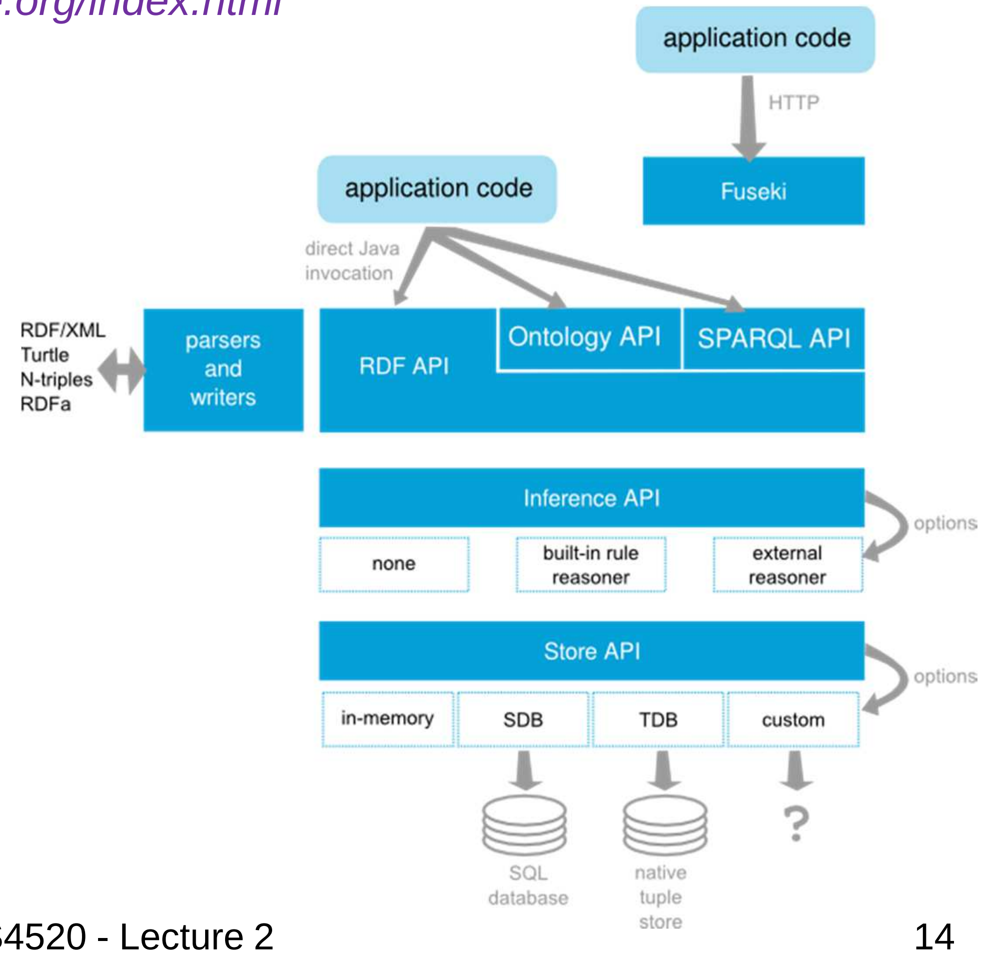
More information: *http://graphdb.ontotext.com/documentation/free/running-graphdb.html*

Apache Jena

Apache Jena is a Java framework (collection of tools and Java libraries) to simplify the development of Semantic Web and Linked Data applications. Link: *http://jena.apache.org/index.html*

Includes:

- RDF API for processing RDF data in various notations
- Ontology API for OWL and RDFS
- Rule-based inference engine and Inference API
- TDB – a native triple store
- SPARQL query processor (called *ARQ*). Supports *Basic Federated SPARQL Query*.
- Servers for publishing RDF data to other applications
  - *Fuseki* – a SPARQL end-point accessible over HTTP



ARQ

practical

- Installation:
  - Download and unzip Jena
  - Set **`JENAROOT`** environmental variable to folder where you unzipped Jena
  - In **`bat`** (Win) or **`bin`** (UNIX) you find **`arq`** executable
- Usage:
  - Prepare a SPARQL query and save it into a file (here: **`query.sparql`**)
  - Prepare some data file (if needed) – e.g. **`data.rdf`**(.**`ttl`**)
  - Execute the query on top of the data by running:

```
arq --query=query.sparql --data=data.rdf
```

- In case of problems use **`arq --help`**

Apache Jena Fuseki

- ***Fuseki*** provides REST-style interaction with RDF data. It is a SPARQL server that provides REST-style SPARQL HTTP Update, SPARQL Query, and SPARQL Update using the SPARQL protocol over HTTP.
- Installation: **practical**
  1. Download (*http://jena.apache.org/download/* or from course webpage) and unzip Fuseki
  2. Set **`FUSEKI_HOME`** and **`FUSEKI_BASE`** environmental variables to folder where you unzipped Fuseki
  3. Start server from Fuseki folder by running: `fuseki-server --update --mem /ds`
     Open *http://localhost:3030/*
     `fuseki-server --update --loc=c:/dir… /ds`
  4. Fuseki can run from a WAR file (fuseki.war). Put the file to the <webapp> folder of Tomcat server and run it. Access Fuseki by: *http://localhost:8080/fuseki/*
  5. Read about other run options from official documentation …
  6. Documentation: *http://jena.apache.org/documentation/fuseki2/*
     http://jena.apache.org/documentation/serving_data

Mulgara

Mulgara – is a RDF database (*successor of Kowari RDF database*).

Link: *http://www.mulgara.org/*

- Written entirely in Java
- Querying language – SPARQL and own TQL
- TQL language:
  - Interpreted querying and command language
  - To manage Mulgara storage (upload, etc.)
- SPARQL – query-only language:
- REST interface for TQL and SPARQL
- Starting the server:
  - Download and unzip the binary package
  - Inside the *Mulgara* folder run: `java -jar mulgara-2.1.13.jar`
  - Web interface: http://localhost:8080/webui/
  - SPARQL REST interface: http://localhost:8080/sparql/

Mulgara

- Create a model: `create <http://localhost/server#myModel>;`
- Insert some RDF triples:

```
insert <http://someServer.com/somePage.html>
<http://purl.org/dc/elements/1.1/title> ‘Some Cool Webpage‘
into <http://localhost/server#myModel>;
```

```
alias <http://purl.org/dc/elements/1.1/> as dc;
insert <http://someServer.com/someOtherPage.html> <dc:title>
  ‘Some Other Cool Webpage' into <http://localhost/server#myModel>;
```

- Upload RDF triples from file
- Query RDF store with TQL or SPARQL query languages:

```
select $subject $predicate $object from <http://localhost/server#myModel>
where $subject $predicate $object;
```

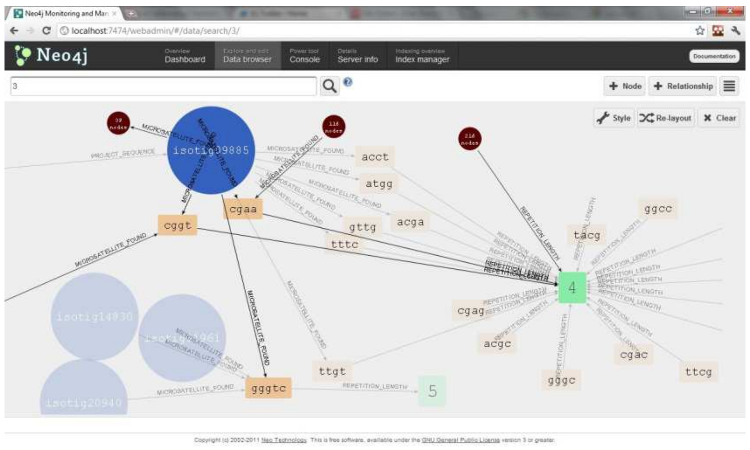
```
alias <http://purl.org/dc/elements/1.1/> as dc;
select $subject $object from <http://localhost/server#myModel>
where $subject <dc:title> $object;
```

AllegroGraph

- ***AllegroGraph*** is a high-performance persistent graph database
- Editions of AllegroGraph: the free *RDFStore* server edition is limited to storing less than 50 million triples, a developer edition capable of storing a maximum of 600 million triples, and an enterprise edition with storage capacity only limited by the underlying server infrastructure.
- Supports SPARQL, RDFS++, and Prolog reasoning
- Supports REST Protocol clients: Java RDF4J (Sesame), Java Jena, Python, C#, Clojure, Perl, Ruby, Scala and Lisp clients.
- Link: *https://allegrograph.com/products/allegrograph/*,
  http://www.franz.com/agraph/allegrograph/
- ***AllegroGraph Web View (AGWebView)*** is a graphical user interface for exploring, querying, and managing AllegroGraph triple stores. It uses HTTP interface to provide the services through a web browser. It is included with the *AllegroGraph*.
- ***Gruff*** - a graph-based triple-store browser for AllegroGraph.
  – Download and unzip the package: *https://allegrograph.com/products/gruff/* , *https://allegrograph.com/gruff-learning-center/*, *http://www.franz.com/agraph/gruff/*
  – Run the browser, create new triple store

Neo4j Graph Database

- ***Neo4j*** is a highly scalable, robust (fully ACID) native graph database, used in mission-critical apps by thousands of leading startups, enterprises, and governments around the world.
  - High Performance for highly connected data
  - High Availability clustering
  - Cypher, a graph query language
  - ETL, easy import with Cypher LOAD CSV
  - Hot Backups and Advanced Monitoring



- Link: *http://neo4j.com/*
  - *http://en.wikipedia.org/wiki/Neo4j*
  - *https://www.youtube.com/channel/UCvze3hU6OZBkB1vkhH2lH9Q*
- *Neo4j Manual* - *http://neo4j.com/docs/stable/index.html*

Part 2

Querying RDF data

SPARQL: General Form

- SPARQL queries take the following general form

```
PREFIX (Namespace Prefixes)
e.g. PREFIX f: <http://example.org#>
```

```
SELECT (Result Set)
e.g. SELECT ?age
```

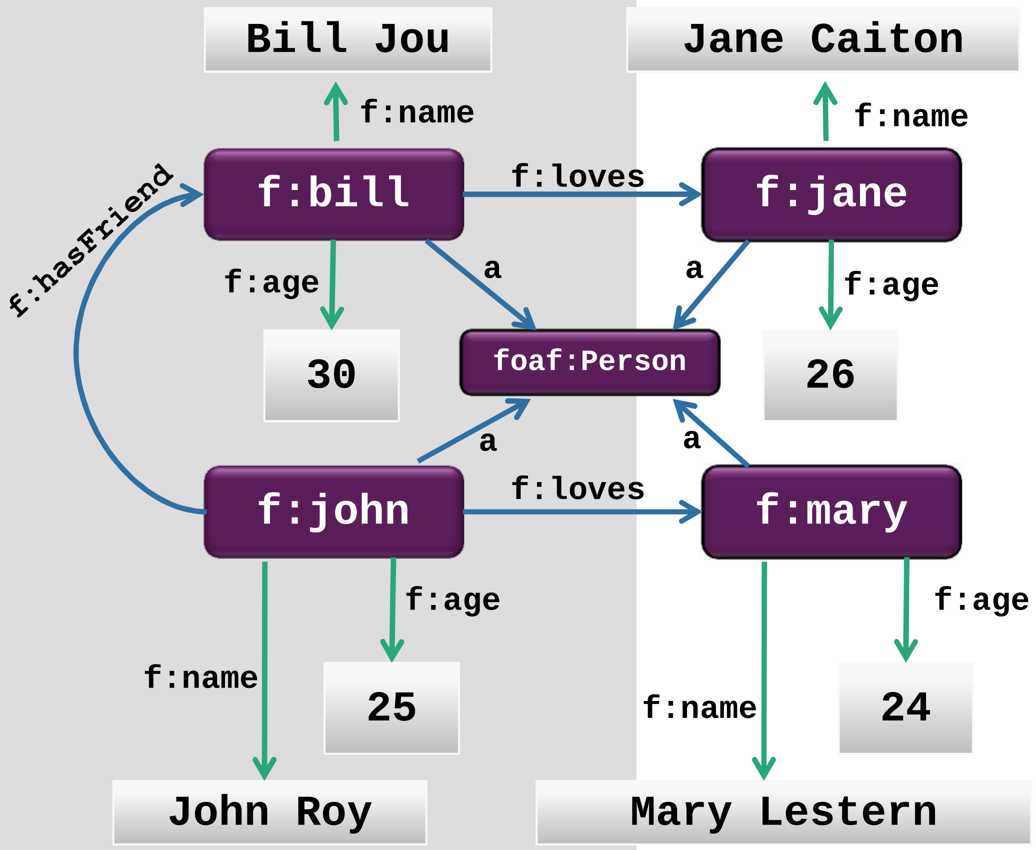
```
FROM and FROM NAMED (Dataset)
e.g. FROM <http://users.jyu.fi/~olkhriye/ties4520/rdf/people.rdf>
```

```
WHERE (Query Triple Pattern)
e.g. WHERE { f:mary f:age ?age }
```

```
ORDER BY, DISTINCT, HAVING, LIMIT, etc. (Modifiers)
e.g. ORDER BY ?age
```

Example data set

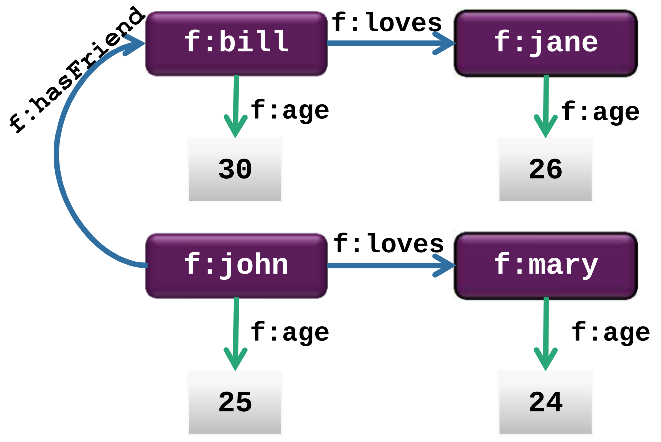
```
@prefix f: <http://example.org#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix foaf: <http://xmlns.com/foaf/0.1/>.

f:john a foaf:Person .
f:bill a foaf:Person .
f:mary a foaf:Person .
f:jane a foaf:Person .
f:john f:age "25"^^xsd:int .
f:bill f:age "30"^^xsd:int .
f:mary f:age "24"^^xsd:int .
f:jane f:age "26"^^xsd:int .
f:john f:loves f:mary .
f:bill f:loves f:jane .
f:john f:hasFriend f:bill.
f:john f:name "John Roy" .
f:bill f:name "Bill Jou" .
f:mary f:name "Mary Lestern" .
f:jane f:name "Jane Caiton" .
f:bill foaf:name "Bill" .
f:john foaf:name "John" .
f:mary foaf:name "Mary" .
f:jane foaf:name "Jane" .
```



Simple SPARQL queries (1)

- Show me the property ***f:age*** of resource ***f:mary***

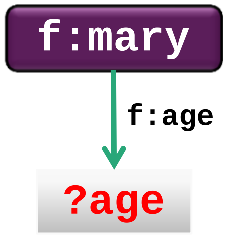
Data



Query

```
SELECT ?age
WHERE { <http://example.org#mary>
<http://example.org#age>  ?age }
```

```
PREFIX f: <http://example.org#>
SELECT ?age
WHERE { f:mary f:age ?age }
```



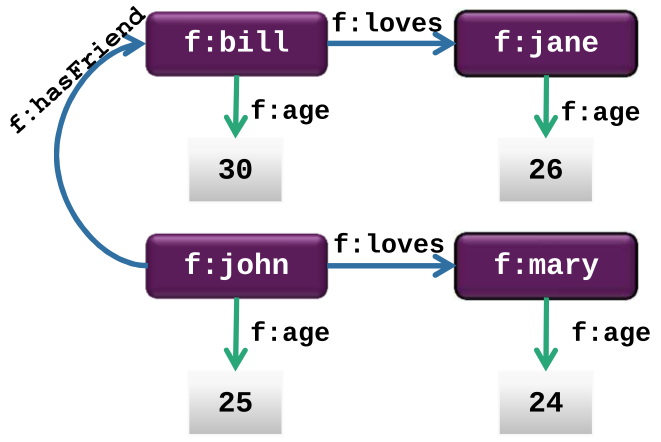
Result

age
24

Simple SPARQL queries (2)

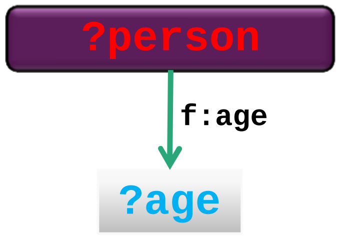
- Show me ***`f:age`*** of all resources

Data



Query

```
PREFIX f: <http://example.org#>
SELECT ?person ?age
WHERE { ?person f:age ?age }
```



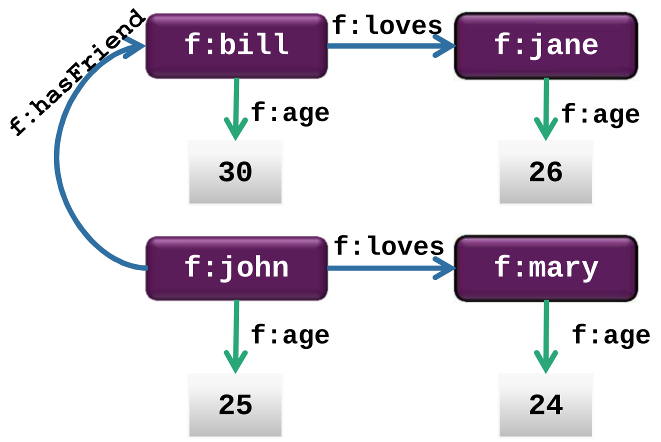
Result

person	age
f:bill	30
f:jane	26
f:john	25
f:mary	24

Simple SPARQL queries (3)

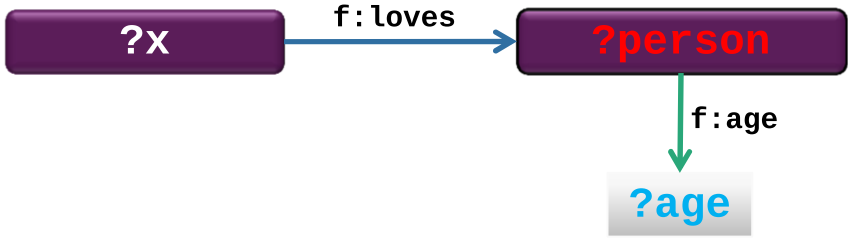
- Show me all things that are loved. Also show me their age (***f:age***)

Data



Query

```
PREFIX f: <http://example.org#>
SELECT ?person ?age
WHERE {
  ?x f:loves ?person .
  ?person f:age ?age
}
```



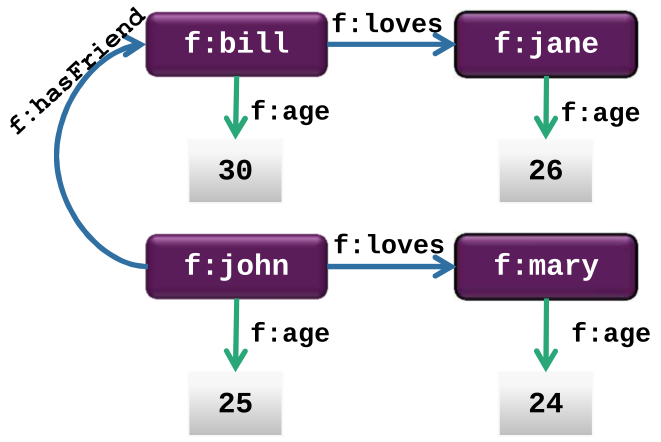
Result

person	age
f:jane	26
f:mary	24

SPARQL: FILTER (testing values)

- Show me people and their age for people older than 25.

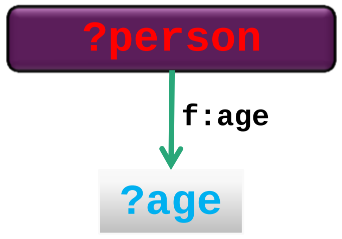
Data



Query

```
PREFIX f: <http://example.org#>
SELECT ?person ?age
WHERE {
  ?person f:age ?age .
  FILTER (?age > 25)
}
```

If *?age* is not a number, then it will not work



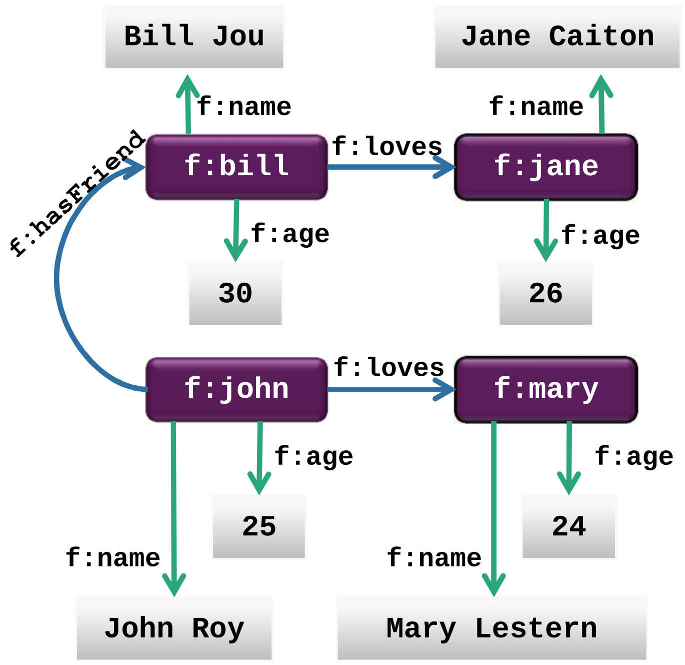
Result

person	age
f:bill	30
f:jane	26

SPARQL: FILTER (string matching)

- Show me people and their name if name has "***r***" or "***R***" in it.

Data



Syntax

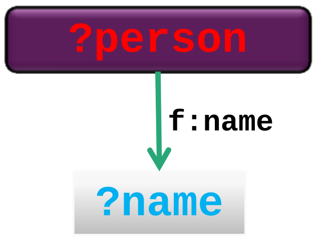
```
FILTER regex(?x, "pattern"[, "flags"])
```

*Flag " **i** " means a case-insensitive pattern*

Query

```
PREFIX f: <http://example.org#>
SELECT ?person ?name
WHERE {
  ?person f:name ?name .
  FILTER regex(?name, "r", "i" )
}
```

Result

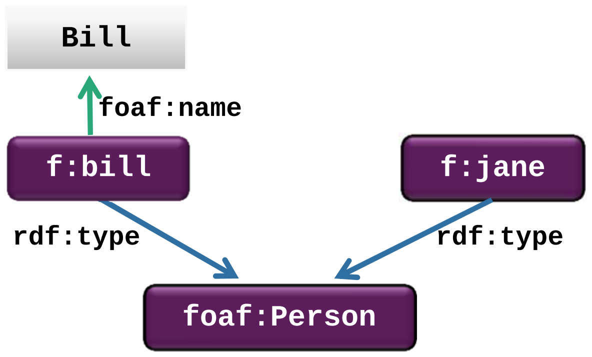


person	name
f:john	John Roy
f:mary	Mary Lestern

SPARQL: FILTER (EXISTS / NOT EXISTS)

- EXISTS expression tests whether the pattern can be found in the data.
- NOT EXISTS expression tests whether the pattern does not match the dataset.

Data



Syntax

```
FILTER EXISTS {“pattern”}
FILTER NOT EXISTS {“pattern”}
```

Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX f: <http://example.org#>

SELECT ?person
WHERE {
  ?person rdf:type foaf:Person .
  FILTER EXISTS {?person foaf:name ?name}
}
```

Result

person
f:bill

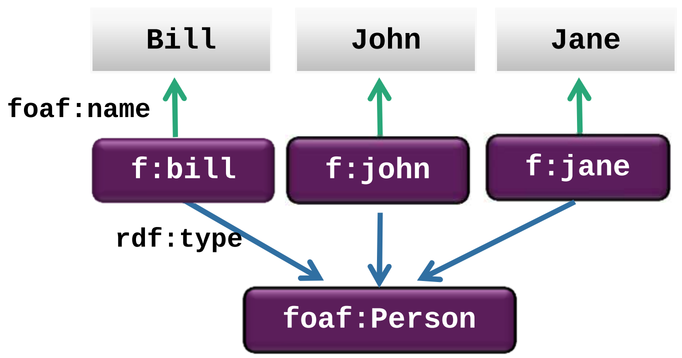
```
SELECT ?person
WHERE {
  ?person rdf:type foaf:Person .
  FILTER NOT EXISTS {?person foaf:name ?name}
}
```

person
f:jane

SPARQL: FILTER (MINUS)

- MINUS removes matches based on the evaluation of two patterns.

Data



Query

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX f: <http://example.org#>

SELECT DISTINCT ?s
WHERE { ?s ?p ?o .
        MINUS { ?s foaf:name "John" . }
}
```

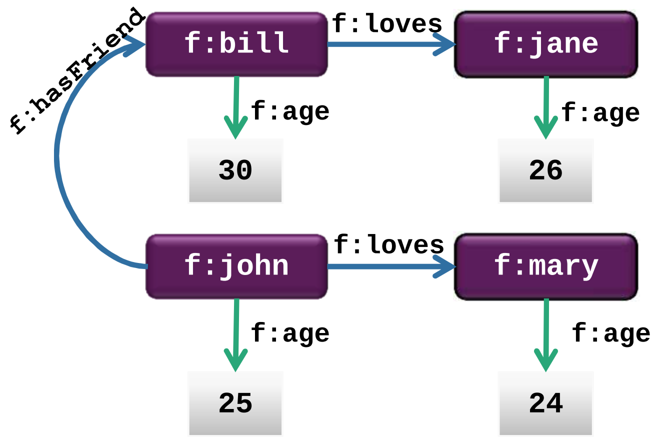
Result

s
f:bill
f:jane

SPARQL: OPTIONAL

- Show me the person and its age (***f:age***). If you have information that person loves somebody, then show it as well.

Data

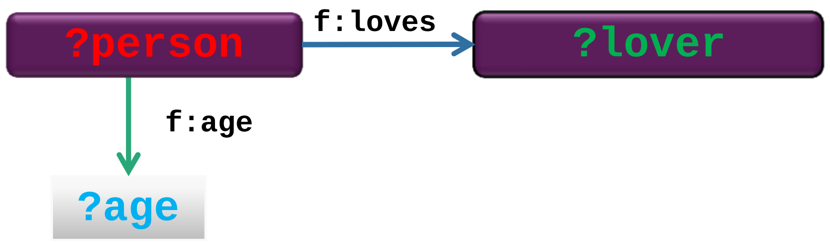


Query

```
PREFIX f: <http://example.org#>
SELECT ?person ?age ?lover
WHERE {
  ?person f:age ?age .
  OPTIONAL {?person f:loves ?lover}
}
```

Result

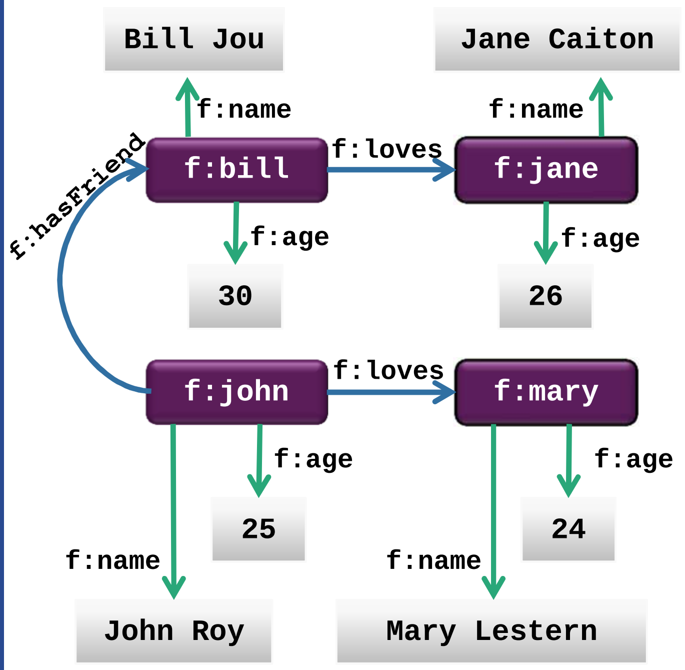
person	age	lover
f:bill	30	f:jane
f:john	25	f:mary
f:mary	24	
f:jane	26	



SPARQL: OPTIONAL with FILTER

- Show me the person and its age (***f:age***). If you have information about that person loving somebody, then show that person if his/her name contains " ***r*** ".

Data



Query

```
PREFIX f: <http://example.org#>
SELECT ?person ?age ?lover
WHERE {
  ?person f:age ?age .
  OPTIONAL {?person f:loves ?lover .
            ?lover f:name ?loverName .
            FILTER regex(?loverName, "r", "i")}
}
```

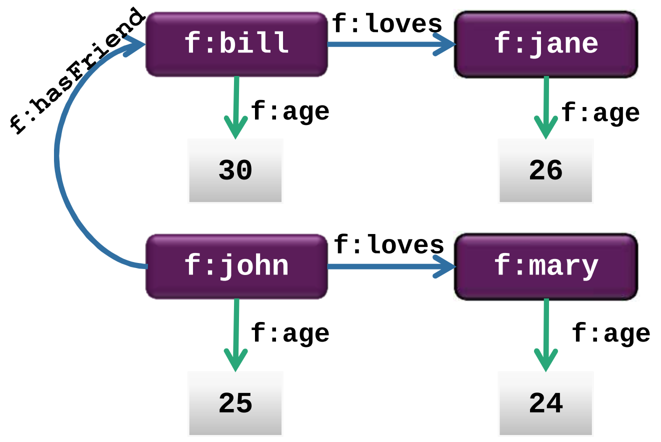
Result

person	age	lover
f:bill	30	
f:john	25	f:mary
f:mary	24	
f:jane	26	

SPARQL: Logical OR (UNION)

- Show me all people who have a friend together with all the people that are younger than 25

Data



Query

```
PREFIX f: <http://example.org#>
SELECT ?person
WHERE {
     {?person f:age ?age . FILTER (?age < 25)}
  UNION
     {?person f:hasFriend ?friend}
}
```

```
PREFIX f: <http://example.org#>
SELECT ?person
WHERE {?person  f:age ?age . FILTER (?age < 25)}
```

+

```
PREFIX f: <http://example.org#>
SELECT ?person
WHERE {?person  f:hasFriend ?friend}
```

Result

person
f:mary
f:john

SPARQL: Solution set modifiers

- Example:

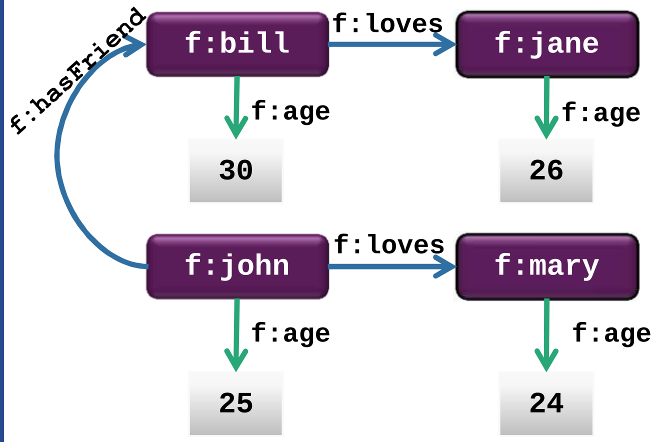
```
PREFIX f: <http://example.org#>
SELECT ?person ?age
WHERE {?person f:age ?age }
ORDER BY ?age
```

- Others:
  - ORDER BY DESC(*?x*)
    - Arrange in descending order
  - LIMIT *n*
    - Include only first *n* solutions
  - OFFSET *n*
    - Include solutions starting from index *n+1*
  - SELECT DISTINCT
    - Do not duplicate solutions
  - SELECT *
    - Return all named variables
  - ASK
    - Yes/No answer (whether or not a solution exists)

SPARQL: Constructing graphs

- Annotate people with age below 26 as young people

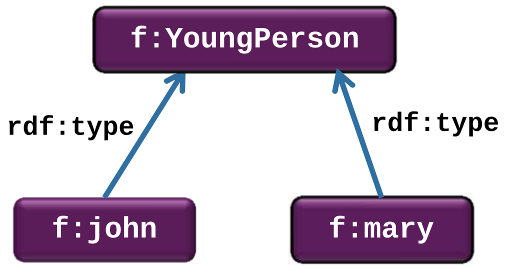
Data



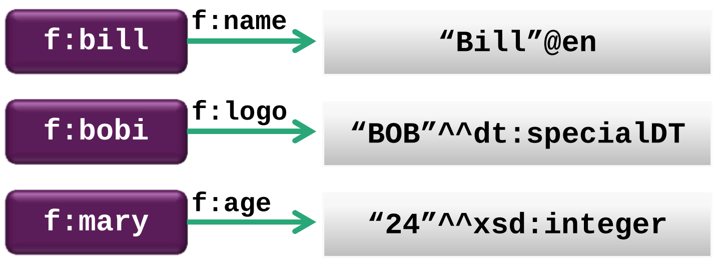
Query

```
PREFIX f: <http://example.org#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

CONSTRUCT { ?person rdf:type f:YoungPerson }

WHERE {?person f:age ?age . FILTER (?age < 26) }
```

Result



Simple SPARQL (matching RDF Literals)



Data

```
@prefix  dt: <http://example.org/datatype#> .
@prefix   f: <http://example.org/ont#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

f:bill f:name "Bill"@en .
f:bobi f:logo "BOB"^^dt:specialDT .
f:bill f:age  "24"^^xsd:integer .
```

- Literals with Language Tags (e.g. ***@en***)

Query *Result*

```
SELECT ?s
WHERE { ?s ?p "Bill" }
```

s

"Bill" is not the same RDF literal as "Bill"@en

```
SELECT ?s
WHERE { ?s ?p "Bill"@en }
```

s
f:bill

- Literals with Numeric Types

```
SELECT ?s
WHERE { ?s ?p 24 }
```

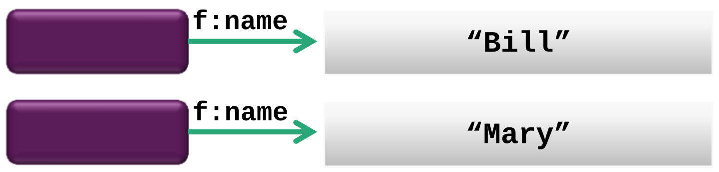
s
f:mary

- Literals with Arbitrary Datatypes

```
PREFIX dt: <http://example.org/datatype#>
SELECT ?s
WHERE { ?s ?p "BOB"^^dt:specialDT }
```

s
f:bobi

Simple SPARQL (Blank Node Labels)



Data

```
@prefix   f: <http://example.org/ont#> .

_:a f:name "Bill" .
_:b f:name "Mary" .
```

Query

```
PREFIX f: <http://example.org/ont#>
SELECT ?s ?:name
WHERE { ?s f:name ?:name }
```

Result

s	name
_:c	"Bill"
_:d	"Mary"

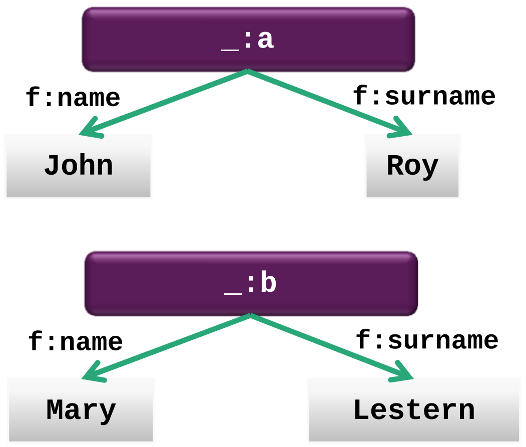
s	name
_:e	"Bill"
_:f	"Mary"

The blank node labels in the result *could be different*, because they only indicate whether RDF terms in the solutions are the same or different.

SPARQL: Functions

- Return the names of the resources as concatenation of ***f:name*** and ***f:surname*** properties' values.

Data



Query

```
PREFIX f: <http://example.org#>

SELECT ?fullName
WHERE {?resource f:name ?name ;
                 f:surname ?surname
       BIND(CONCAT(?name," ",?surname) AS ?fullName)
}
```

Result

fullName
”John Roy”
”Mary Lestern”

SPARQL: Functions

- SPARQL Query language has a set of functions:
  - Functional Forms (BOUND, IF, COALESCE, NOT EXISTS / EXISTS, IN / NOT IN, etc.)
  - Functions on RDF Terms
  - Functions on Strings
  - Functions on Numerics
  - Functions on Dates and Times
  - Hash Functions

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

TriG notation for RDF1.1

- ***TriG*** is an extension of the *Turtle* format, extended to support representing a complete *RDF Dataset* in a compact and natural text form. Link: *http://www.w3.org/TR/trig/*

N-Quads

```
<http://example.org/John> <http://example.org/hasName> "John" <http://example.org/graph1> .
          <…>                       <…>                 "…"   <http://example.org/graph1> .
<http://example.org/Mary> <http://example.org/hasName> "Mary" <http://example.org/graph2> .
          <…>                       <…>                 "…"   <http://example.org/graph2> .
…
```

TriX

```
<TriX xmlns="http://www.w3.org/2004/03/trix/trix-1/">
  <graph>
    <uri>http://example.org/graph1</uri>
    <triple>
      <uri>http://example.org/John</uri>
      <uri>http://example.org/hasName</uri>
      <plainLiteral>John</plainLiteral>
    </triple>
    <triple>
    …
    </triple>
  </graph>
  <graph>
    <uri>http://example.org/graph2</uri>
    <triple>
      <uri>http://example.org/Mary</uri>
      <uri>http://example.org/hasName</uri>
      <plainLiteral>Mary</plainLiteral>
    </triple>
    <triple>
    …
    </triple>
  </graph>
</TriX>
```

TriG

```
@prefix ex: <http://example.org/>.

# default graph
    {    …    }

<http://example.org/graph1>
{ ex:John ex:hasName  "John" .
  …   }

<http://example.org/graph2>
{ ex:Mary ex:hasName  "Mary" .
  …   }
```

```
@prefix ex: <http://example.org/>.

# default graph
    {    …    }

ex:graph1 { ex:John ex:hasName  "John" .
              …
            }
ex:graph2 { ex:Mary ex:hasName  "Mary" .
              …
            }
```

SPARQL: RDF Dataset

- Finding matches in a specific graph.

```
#Default graph (located at http://users.jyu.fi/graphs.ttl)
@prefix dc: <http://purl.org/dc/elements/1.1/> .
<http://example.org/bob>    dc:publisher  "Bob Hacker" .
<http://example.org/alice>  dc:publisher  "Alice Hacker" .
```

```
#Named graph: http://example.org/bob
@prefix f: <http://example.org#> .
_:a f:name "Bob" .
_:a f:age “25” .
```

```
#Named graph: http://example.org/alice
@prefix f: <http://example.org#> .
_:a f:name “Alice" .
_:a f:age “22” .
```

Query

```
PREFIX f: <http://example.org#>
PREFIX dc: <http://purl.org/dc/elements/1.1/>

SELECT ?graph ?name ?age
WHERE {
  ?graph dc:publisher ?who .
  GRAPH ?graph {?person f:name ?name .
                ?person f:age ?age }
}
```

Result

graph	name	age
<http://example.org/bob>	Bob	25
<http://example.org/alice>	Alice	22

SPARQL: several sources

```
f:john f:age "25"^^xsd:integer .
f:bill f:age "30"^^xsd:integer .
f:mary f:age "24"^^xsd:integer .
f:jane f:age "26"^^xsd:integer .
f:john f:loves f:mary .
f:bill f:loves f:jane .
f:john f:hasFriend f:bill
```

http://users.jyu.fi/~olkhriye/ties4520/rdf/people.rdf

```
j:teacher rdf:type j:EducationJob .
j:seniorResearcher rdf:type j:ResearchJob .
j:juniorResearcher rdf:type j:ResearchJob .
j:professor rdf:type j:ResearchJob, j:EducationJob .
```

http://users.jyu.fi/~olkhriye/ties4520/rdf/jobs.rdf

```
f:john e:worksAs j:teacher .
f:mary e:worksAs j:seniorResearcher .
f:jane e:worksAs j:juniorResearcher .
f:bill e:worksAs j:professor .
```

http://users.jyu.fi/~olkhriye/ties4520/rdf/employment.rdf

From now on prefixes will be omitted to save space

```
@prefix j: <http://jyu.fi/jobs#> .
@prefix e: <http://jyu.fi/employment#> .
@prefix f: <http://example.org#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
```

Prefixes

SPARQL: several sources

- Show me people, their age and their job, if a job is related to education.

Query

```
…
SELECT ?person ?age ?job
FROM <http://users.jyu.fi/~olkhriye/ties4520/rdf/employment.rdf>
FROM <http://users.jyu.fi/~olkhriye/ties4520/rdf/people.rdf>
FROM <http://users.jyu.fi/~olkhriye/ties4520/rdf/jobs.rdf>
WHERE {
  ?person f:age ?age .
  ?person e:worksAs ?job .
  ?job rdf:type j:EducationJob .
}
```

Result

person	age	job
f:bill	30	j:professor
f:john	25	j:teacher

```
FROM < URI >
FROM NAMED < URI >
```

- is used to identify the contents to be in the default graph

- is used to identify a named graph

URI refers a Graph ID…

It *is not* a distributed query among separate RDF files. It is used just to define more specific (sub) dataset for the particular query.

SPARQL: several sources

Use ***SERVICE*** clause for federated queries.

- The *SERVICE* keyword instructs a federated query processor to invoke a portion of a SPARQL query against a *remote SPARQL endpoint* (*not a RDF file*).

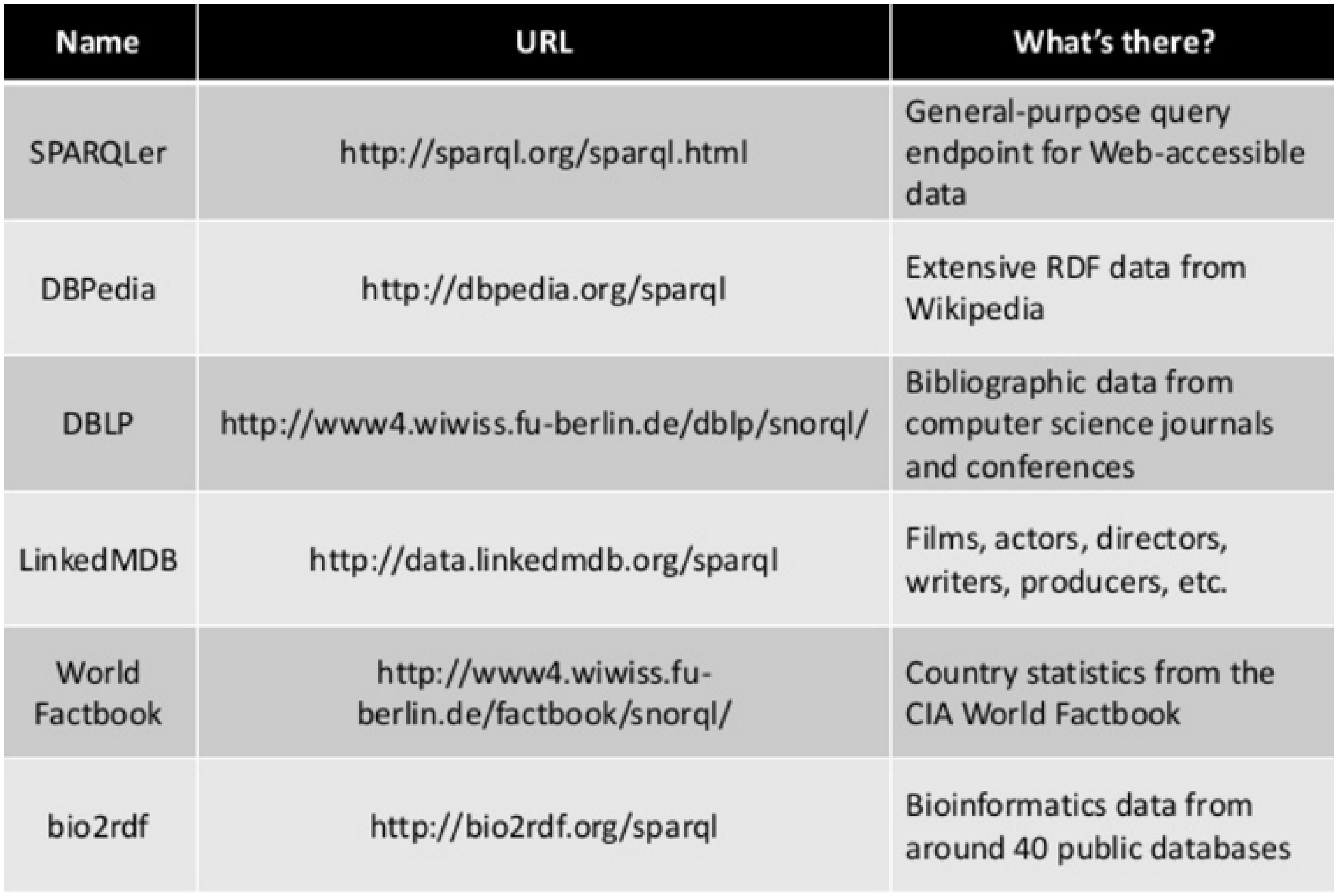
Query

```
…
PREFIX ex: <http://users.jyu.fi/~olkhriye/ties4520/rdf/>
SELECT ?person ?age ?job
WHERE {
  SERVICE ex:people {?person f:age ?age .}
  SERVICE ex:employment {?person e:worksAs ?job .}
  SERVICE ex:jobs {?job rdf:type j:EducationJob .}
}
```

Result

person	age	job
f:bill	30	j:professor
f:john	25	j:teacher

Some Public SPARQL Endpoints



Name	URL	What's there?
SPARQLer	http://sparql.org/sparql.html	General-purpose query endpoint for Web-accessible data
DBPedia	http://dbpedia.org/sparql	Extensive RDF data from Wikipedia
DBLP	http://www4.wiwiss.fu-berlin.de/dblp/snorql/	Bibliographic data from computer science journals and conferences
LinkedMDB	http://data.linkedmdb.org/sparql	Films, actors, directors, writers, producers, etc.
World Factbook	http://www4.wiwiss.fu-berlin.de/factbook/snorql/	Country statistics from the CIA World Factbook
bio2rdf	http://bio2rdf.org/sparql	Bioinformatics data from around 40 public databases

Triple store SPARQL Endpoints

RDF4J workbench:

- *http://localhost:8080/rdf4j-server/repositories/ <repository name>*

GraphDB:

- *http://localhost:7200/repositories/ <repository name>*

Apache Jena Fuseki:

- *http://localhost:8080/fuseki/ <repository name> /query or sparql*
- *http://localhost:3030/ <repository name> /query or sparql*

SPARQL1.1: Update

- INSERT DATA and DELETE DATA

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
```

```
INSERT DATA { <http://example/book1> dc:title "A new book" ;
                                     dc:creator "A.N.Other" .
            }
```

```
DELETE DATA { GRAPH <http://example/bookStore>
                     { <http://example/book2> dc:title "David Copperfield";
                                              dc:creator "Edmund Wells" .
                     }
            }
```

- Documentation: *http://www.w3.org/TR/sparql11-update/*

SPARQL1.1: Update

- DELETE / INSERT

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
```

```
DELETE { ?book ?p ?v }
WHERE  { ?book dc:date ?date .
         FILTER ( ?date > "1970-01-01T00:00:00-02:00"^^xsd:dateTime )
         ?book ?p ?v
       }
```

```
WITH <http://example/addresses>
DELETE { ?person foaf:givenName 'Bill' }
INSERT { ?person foaf:givenName 'William' }
WHERE  { ?person foaf:givenName 'Bill' }
```

```
INSERT { GRAPH <http://example/bookStore2> { ?book ?p ?v } }
WHERE  { GRAPH  <http://example/bookStore>
           { ?book dc:date ?date .
             FILTER ( ?date < "2000-01-01T00:00:00-02:00"^^xsd:dateTime )
             ?book ?p ?v } } ;
WITH <http://example/bookStore>
DELETE { ?book ?p ?v }
WHERE  { ?book dc:date ?date ;
               dc:type dcmitype:PhysicalObject .
         FILTER ( ?date < "2000-01-01T00:00:00-02:00"^^xsd:dateTime )
         ?book ?p ?v }
```

- Documentation: *http://www.w3.org/TR/sparql11-update/*

SPARQL1.1: Update

- DELETE WHERE

```
PREFIX dc: <http://purl.org/dc/elements/1.1/>
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
```

```
DELETE WHERE { ?person foaf:givenName 'Fred';
                       ?property      ?value }
```

```
DELETE WHERE { GRAPH <http://example.com/names>
                     { ?person foaf:givenName 'Fred' ;
                               ?property1     ?value1
                     }
               GRAPH <http://example.com/addresses>
                     { ?person ?property2 ?value2  }
             }
```

- LOAD operation reads an RDF document from a IRI and inserts its triples into the specified graph in the Graph Store.

```
LOAD ( SILENT )? IRIref_from ( INTO GRAPH IRIref_to )?
```

- CLEAR operation removes all the triples in the specified graph(s) in the Graph Store.

```
CLEAR  ( SILENT )? (GRAPH IRIref | DEFAULT | NAMED | ALL )
```

- Documentation: *http://www.w3.org/TR/sparql11-update/*

SPARQL1.1: Update (Graph Management)

- CREATE creates a new graph in stores that support empty graphs. The contents of already existing graphs remain unchanged.

```
CREATE ( SILENT )? GRAPH IRIref
```

- DROP removes a graph and all of its contents (DROP DEFAULT is equivalent to CLEAR DEFAULT).

```
DROP  ( SILENT )? (GRAPH IRIref | DEFAULT | NAMED | ALL )
```

- COPY modifies a graph to contain a copy of another. It inserts all data from an input graph into a destination graph. Data from the destination graph, if any, is removed before insertion.

```
COPY (SILENT)? ((GRAPH)? IRIref_from | DEFAULT) TO ((GRAPH)? IRIref_to | DEFAULT)
```

```
DROP SILENT (GRAPH IRIref_to | DEFAULT);
INSERT {(GRAPH IRIref_to)? {?s ?p ?o}} WHERE {(GRAPH IRIref_from)? {?s ?p ?o}}
```

- MOVE moves all of the data from one graph into another. The input graph is removed after insertion and data from the destination graph, if any, is removed before insertion.

```
MOVE (SILENT)? ((GRAPH)? IRIref_from | DEFAULT) TO ((GRAPH)? IRIref_to | DEFAULT)
```

```
DROP SILENT (GRAPH IRIref_to | DEFAULT);
INSERT {(GRAPH IRIref_to)? {?s ?p ?o}} WHERE {(GRAPH IRIref_from)? {?s ?p ?o}};
DROP ( GRAPH IRIref_from | DEFAULT)
```

- ADD reproduces all data from one graph into another. Data from the input graph is not affected, and initial data from the destination graph, if any, is kept intact.

```
ADD (SILENT)? ((GRAPH)? IRIref_from | DEFAULT) TO ((GRAPH)? IRIref_to | DEFAULT)
```

```
INSERT {(GRAPH IRIref_to)? {?s ?p ?o}} WHERE {(GRAPH IRIref_from)? {?s ?p ?o}}
```

- Documentation: *http://www.w3.org/TR/sparql11-update/*

More on SPARQL

- Official specification:
  - *http://www.w3.org/TR/sparql11-query/*
- SPARQL update
  - *http://www.w3.org/TR/sparql11-update/*
- SPARQL 1.1 Federated Query
  - *https://www.w3.org/TR/2013/REC-sparql11-federated-query-20130321/#simpleService*
  - *https://www.w3.org/TR/sparql11-federated-query/*
  - *http://www.snee.com/bobdc.blog/2010/01/federated-sparql-queries.html*
- Other SPARQL tutorials:
  - *https://jena.apache.org/tutorials/sparql.html*
- SPARQL endpoints:
  - *https://www.w3.org/wiki/SparqlEndpoints*
- SPARQL extensions:
  - *https://www.w3.org/wiki/SPARQL/Extensions*

Apache Jena Fuseki

- Since Fuseki v3 stars to support TriG format as well, you can upload data in TriG format directly from the file. But, there is a possibility to define named graphs in the structure of repository in other way. If you noticed, there is a possibility to provide Graph Id while uploading a file. So… you may create 2 Turtle files. First one should contain triples from default graph of initial TriG document, second file should contain triples from the named graph. Specify corresponding graph ID while uploading the files ("default" for the first file, <*id of the named graph*> for the second).
- Fuseki *does not support "#"* character in the graph URI (drops out the rest starting form #). Use "*/*" character instead of "#".
- Fuseki has following URLs of SPARQL Endpoints:
  - http://localhost:3030/repName/query - for SPARQL queries;
  - http://localhost:3030/repName/update - for SPARQL UPDATE queries.
- Fuseki distinguishes content of default and named graphs. If you do not use *GRAPH <grophID>* in the query pattern and specify only triples, query engine associates the triples only with content of default graph.

In contrast, *RDF4J (Sesame)* "ignores" association with graphs, if you use just triples in the query pattern, and treats quads (quadruples) as triples. It looks like triples of all the named graphs are considered as triples of default graph.

Empty Graphs

- SPARQL UPDATE query *CREATE GRAPH <graphID>* executes properly, but does not actually creates an empty graph.
- You can use new graph IDs in SPARQL UPDATE queries and corresponding graph will be created automatically.
- If the content of the named graph become empty (is deleted), such empty graph disappears from the repository.

In contrast to *Fuseki*, *RDF4J (Sesame)* considers any empty graph as existing graph (any empty subset is a part of a set).

Task 2