RDF, ShEx and Entity Schemas

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Overview

Why RDF, ShEx and entity schemas?

RDF data model

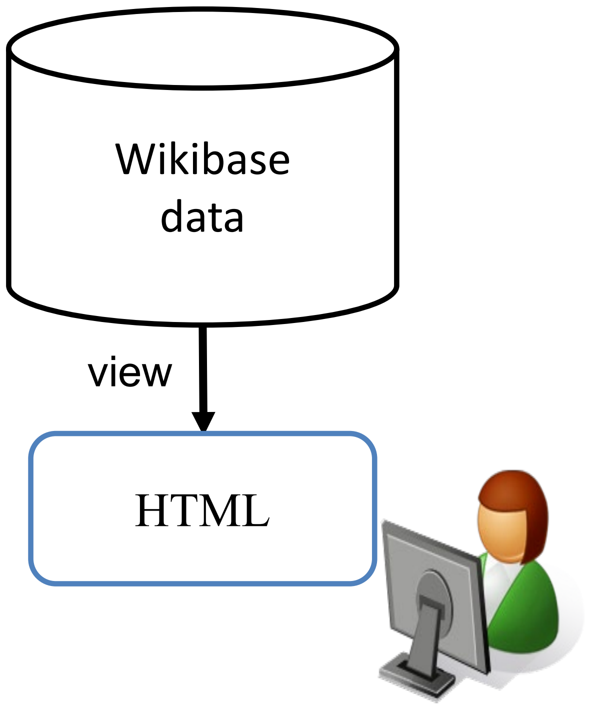
Wikibase data model and RDF

ShEx

Entity schemas

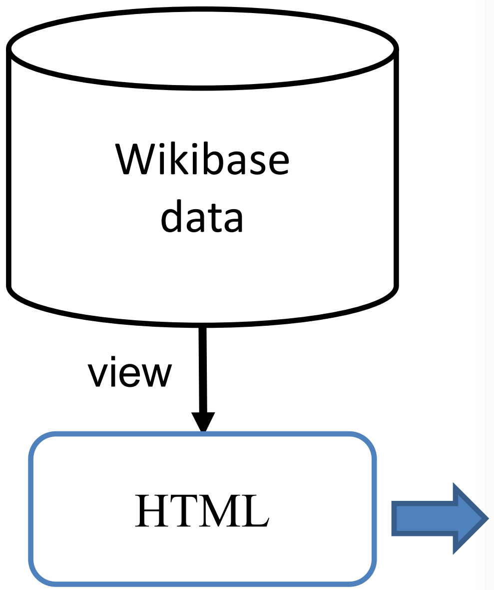
Traditional web

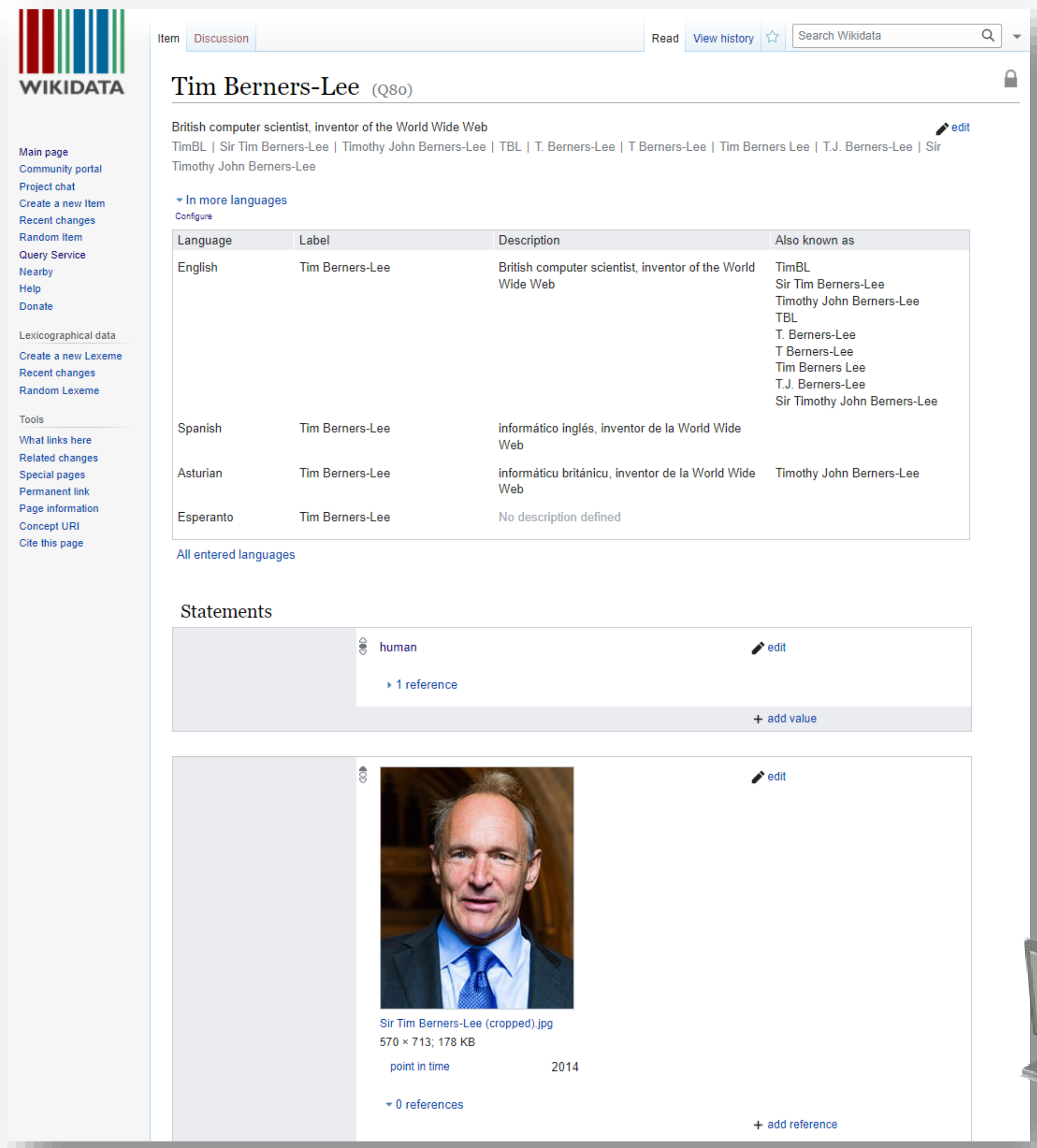
Provide HTML for humans to browse



Example (Q80)

Tim Berners-Lee



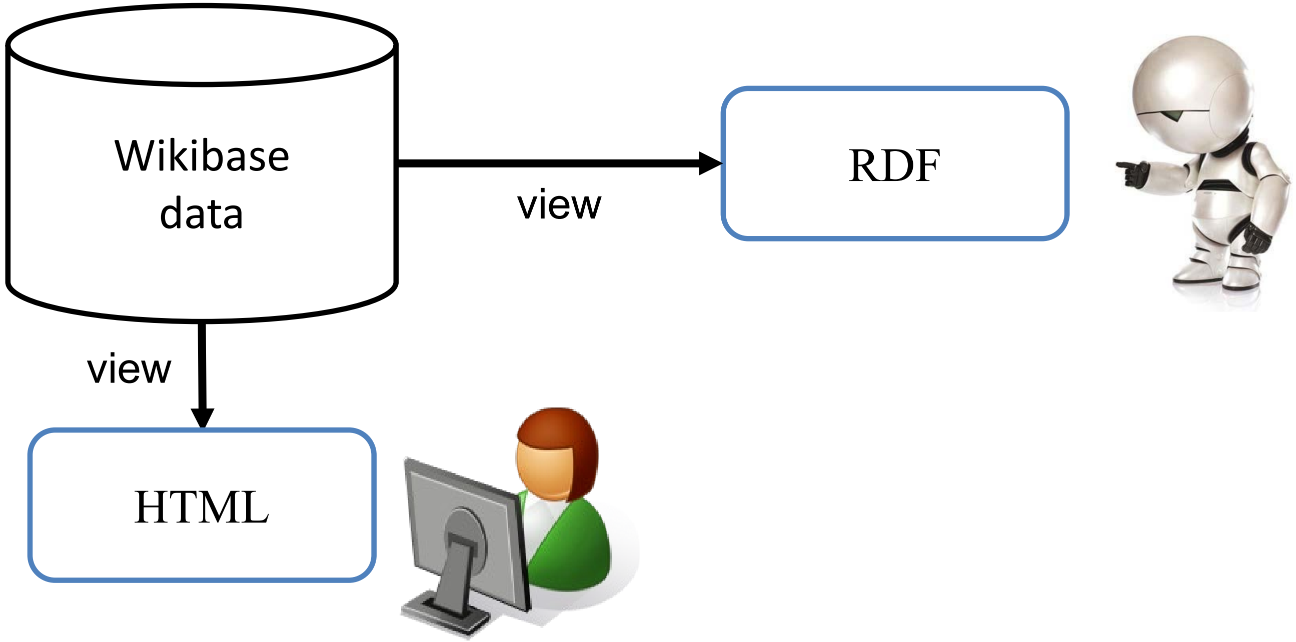


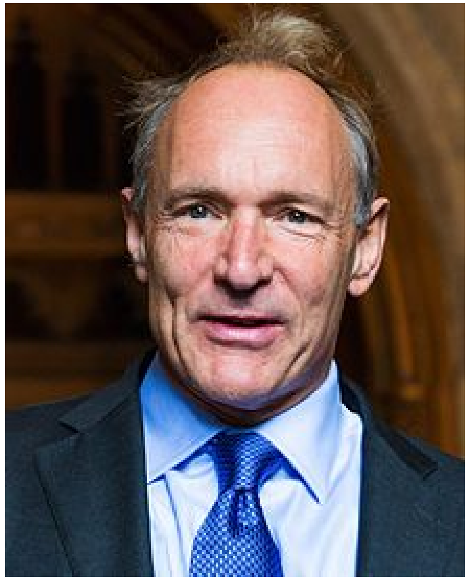
Try it: http://www.wikidata.org/entity/Q80

Semantic web

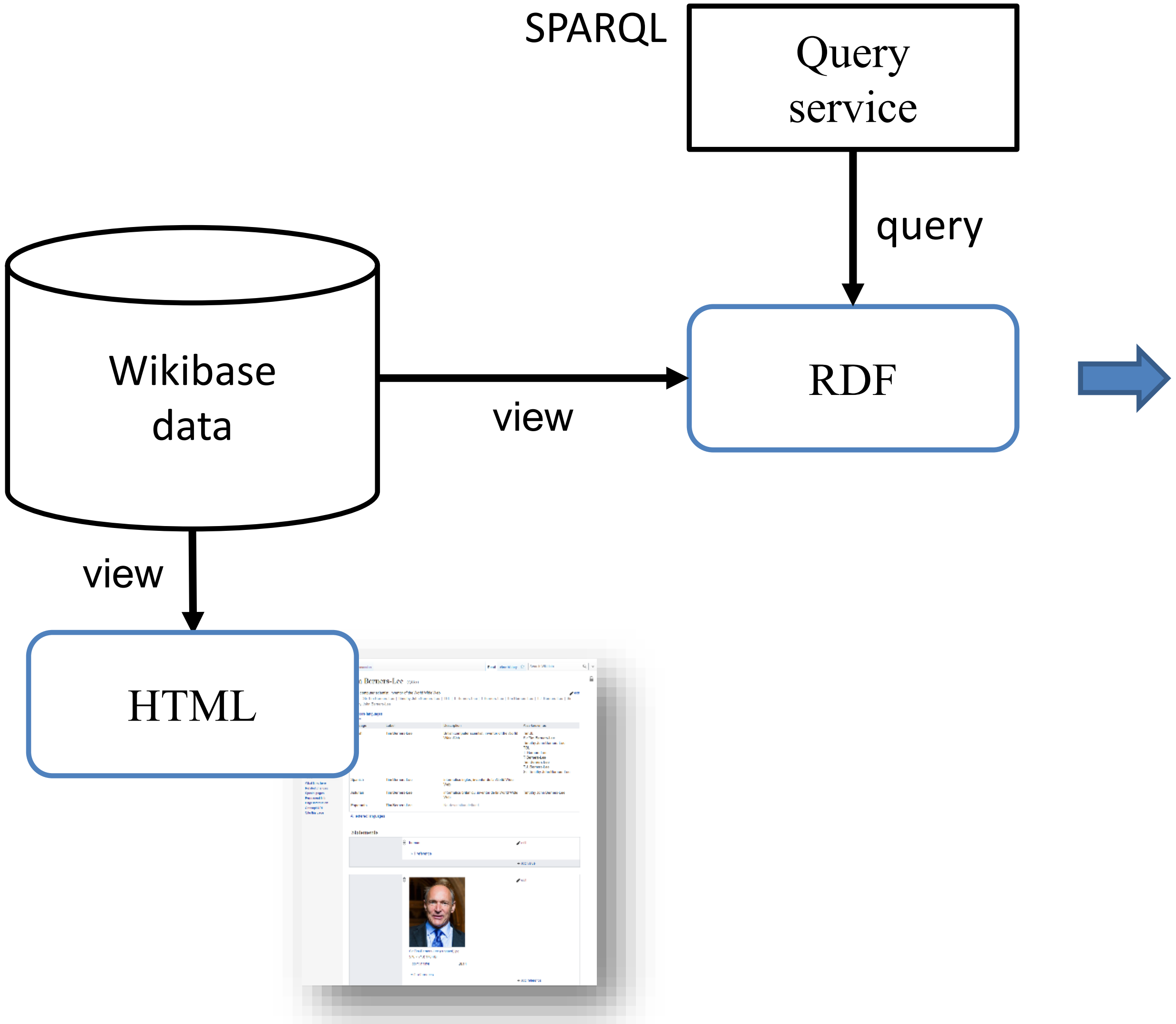
Data for humans (HTML) and for machines (RDF)

Web of data + web of documents





RDF view



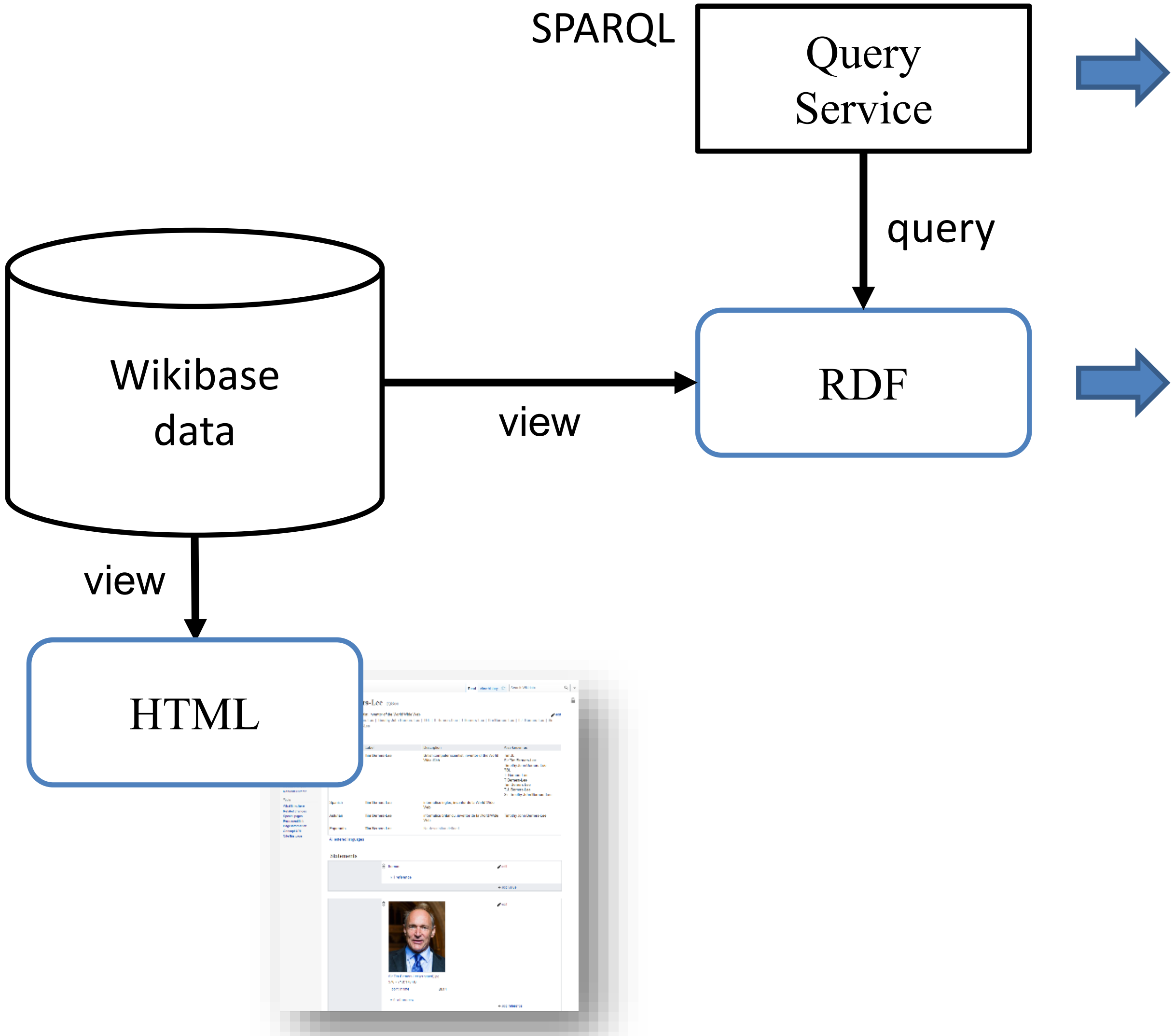

```
wd:Q80 a wikibase:Item ;
 rdfs:label "Tim Berners-Lee"@en;
 wdt:P31    wd:Q5 ;
 wdt:P18    <http://commons.wikimedia.org/...jpg> ;
 wdt:P19    wd:Q84 ;
. . .
```

Content negotiation

Each item has a concept URI (`http://www.wikidata.org/entity/Q80`)

System redirects to HTML, RDF, JSON, views depending on client

SPARQL query service




```
SELECT ?picure ?birthPlace WHERE {
  wd:Q80 wdt:P18 ?picture    ;
         wdt:P19 ?birthPlace .
}
```

```
wd:Q80 a wikibase:Item ;
 rdfs:label "Tim Berners-Lee"@en;
 wdt:P31    wd:Q5 ;
 wdt:P18    <http://commons.wikimedia.org/...jpg> ;
 wdt:P19    wd:Q84 ;
. . .
```

Try it: https://w.wiki/4exN

RDF and SPARQL, the good parts

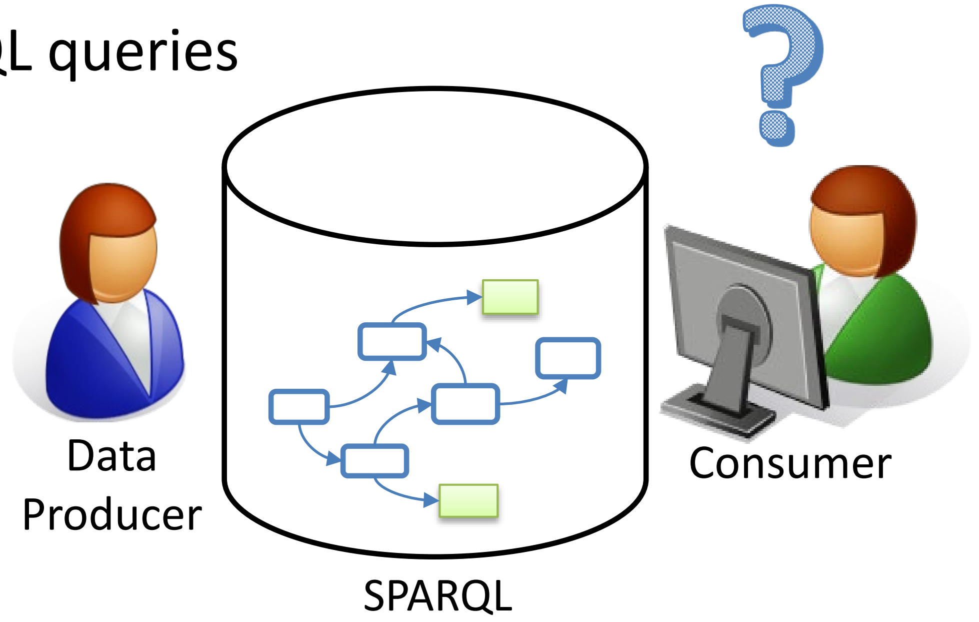
- Interoperability
  - RDF as a communication language
  - Basis for knowledge representation
- Flexibility
  - Graph data can be adapted to multiple models
  - No need to fix a schema before adding statements
- Reusability and existing tools
  - Part of the semantic web stack: existings tools and specs
  - RDF data stores and SPARQL endpoints
  - Wikidata query service is really great

Wikidata is one of the best showcases of semantic web

RDF and SPARQL, the other parts...

Consuming & producing RDF

- Describing and validating RDF content
- SPARQL endpoints can be overwhelming
  - Typical documentation = set of example SPARQL queries
  - Difficult to know where to start doing queries



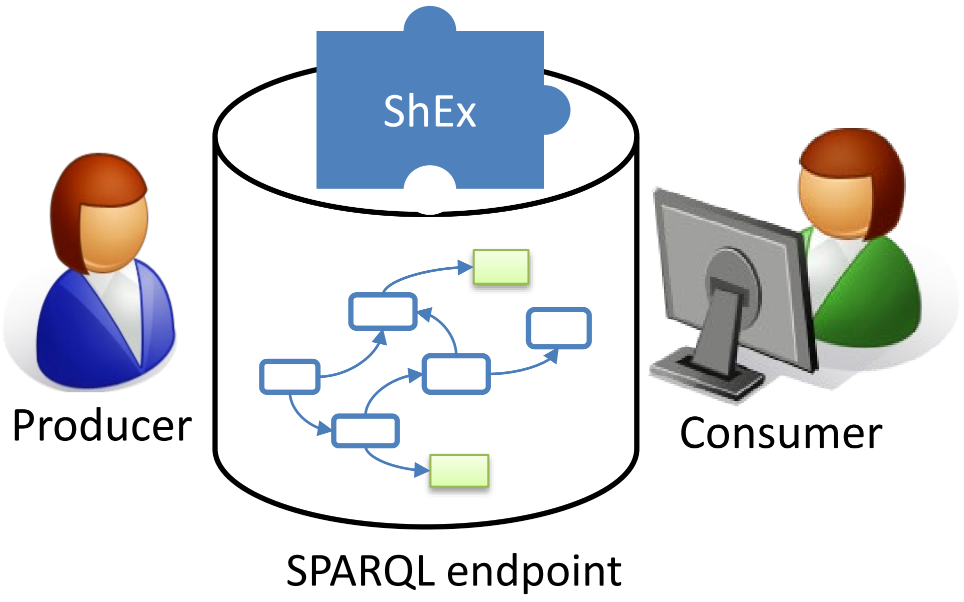
Why describe & validate RDF?

For producers

- Developers can understand the contents they are going to produce
- They can ensure they produce the expected structure
- Advertise and document that structure
- Generate interfaces

For consumers

- Understand the contents
- Verify the structure before processing it
- Query generation & optimization

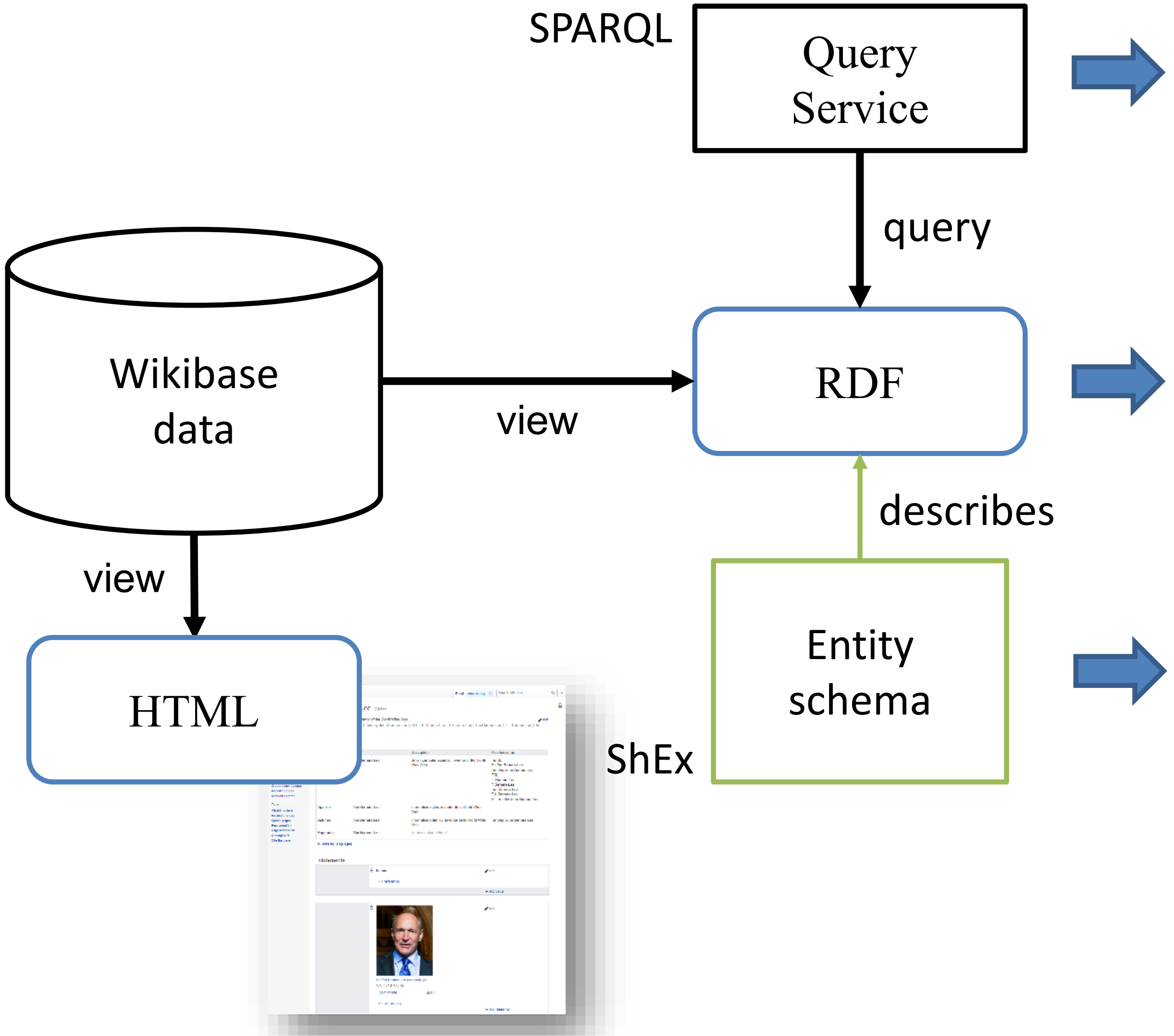


Similar technologies

Technology	Schema
Relational Databases	DDL
XML	DTD, XML Schema, RelaxNG, Schematron
Json	Json Schema
RDF	ShEx

Fill that gap

Example (Q80)




```
SELECT ?picure ?birthPlace WHERE {
  wd:Q80 wdt:P18 ?picture    ;
         wdt:P19 ?birthPlace .
}
```

```
wd:Q80 a wikibase:Item ;
 rdfs:label "Tim Berners-Lee"@en;
 wdt:P31    wd:Q5 ;
 wdt:P18    <http://commons.wikimedia.org/...jpg> ;
 wdt:P19    wd:Q84 ;
. . .
```

```
<Person> {
  wdt:P31 @<Human>   ;
  wdt:P18 @<Picture> ;
  wdt:P19 @<Place>
}
<Human>   [ wd:Q5 ]
<Place>   {}
<Picture> IRI
```

Introduction to the RDF data model

RDF

RDF = Resource description framework

Based on triples and URIs to represent properties and nodes

Short history

- Around 1997 - PICS, Dublin core, Meta Content Framework
- 1997 1st Working draft https://www.w3.org/TR/WD-rdf-syntax-971002, RDF/XML
- 1999 1st W3C Rec https://www.w3.org/TR/1999/REC-rdf-syntax-19990222/, XML Syntax, first applications RSS, EARL
- 2004 - RDF Revised https://www.w3.org/TR/2004/REC-rdf-concepts-20040210/, SPARQL, Turtle, Linked Data
- 2014 - RDF 1.1 https://www.w3.org/TR/rdf11-concepts/, SPARQL 1.1, JSON-LD

RDF Data Model

RDF is made from statements

subject --predicate--> object

Statement = a triple (subject, predicate, object)

Example:

http://www.wikidata.org/entity/Q80 --http://www.wikidata.org/prop/direct/P19--> http://www.wikidata.org/entity/Q84

subject | predicate | object

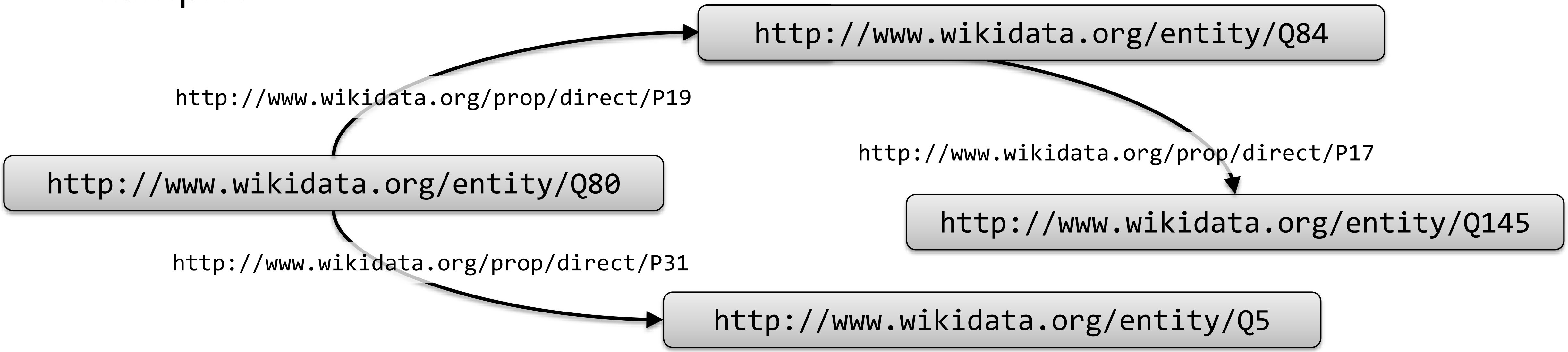
N-Triples representation

```
<http://www.wikidata.org/entity/Q80> <http://www.wikidata.org/prop/direct/P19> <http://www.wikidata.org/entity/Q84> .
```

Set of statements = RDF graph

RDF data model = directed graph

Example:



N-triples representation

```
<http://www.wikidata.org/entity/Q80> <http://www.wikidata.org/prop/direct/P19> <http://www.wikidata.org/entity/Q84> .
<http://www.wikidata.org/entity/Q84> <http://www.wikidata.org/prop/direct/P17> <http://www.wikidata.org/entity/Q145> .
<http://www.wikidata.org/entity/Q80> <http://www.wikidata.org/prop/direct/P31> <http://www.wikidata.org/entity/Q5> .
```

subject predicate object

Turtle notation

Human readable notation that simplifies N-Triples

Allows namespace declarations and some abreviations

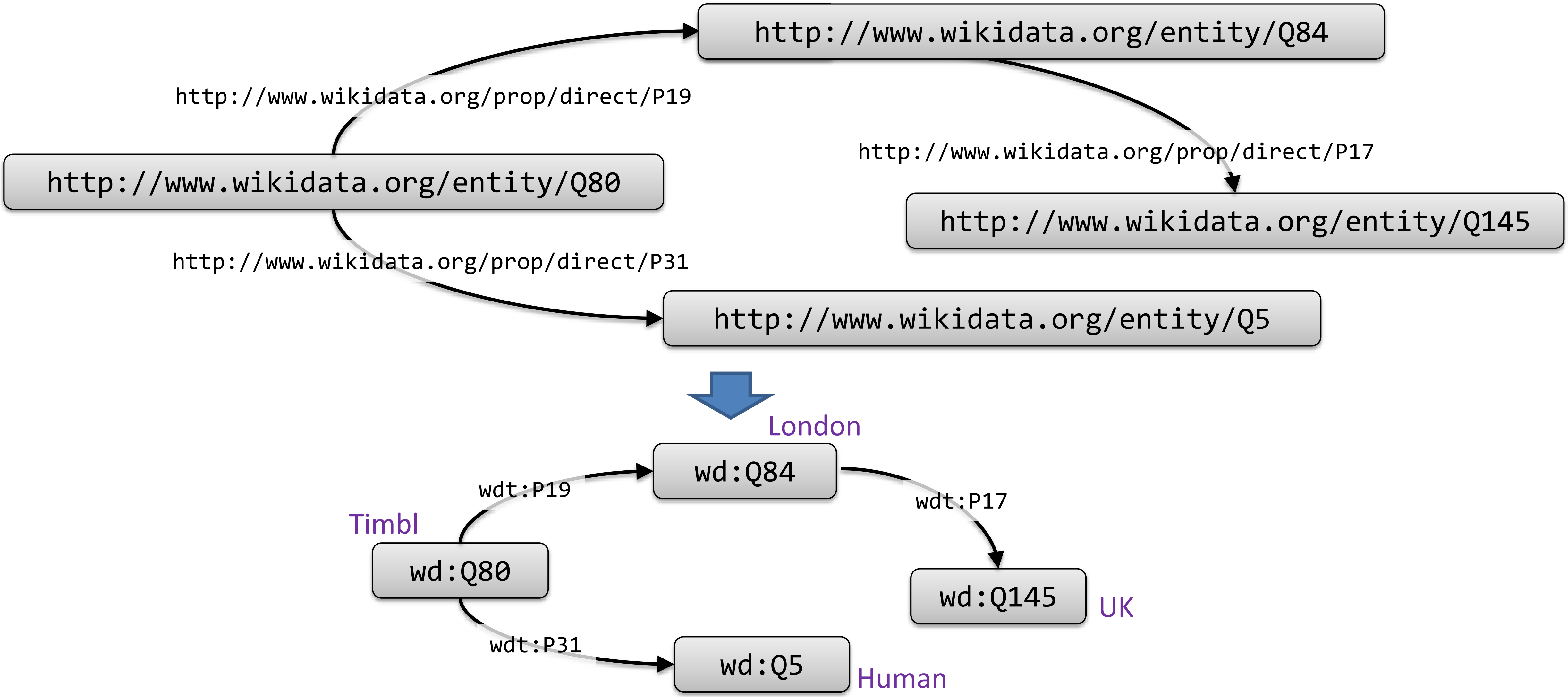
N-Triples

```
<http://www.wikidata.org/entity/Q84> <http://www.wikidata.org/prop/direct/P17> <http://www.wikidata.org/entity/Q145> .
<http://www.wikidata.org/entity/Q80> <http://www.wikidata.org/prop/direct/P19> <http://www.wikidata.org/entity/Q84> .
<http://www.wikidata.org/entity/Q80> <http://www.wikidata.org/prop/direct/P31> <http://www.wikidata.org/entity/Q5> .
```

Turtle

```
prefix wd: <http://www.wikidata.org/entity/>
prefix wdt: <http://www.wikidata.org/prop/direct/>

wd:Q80 wdt:P19 wd:Q84 ;
       wdt:P31 wd:Q5 .
wd:Q84 wdt:P17 wd:Q145 .
```

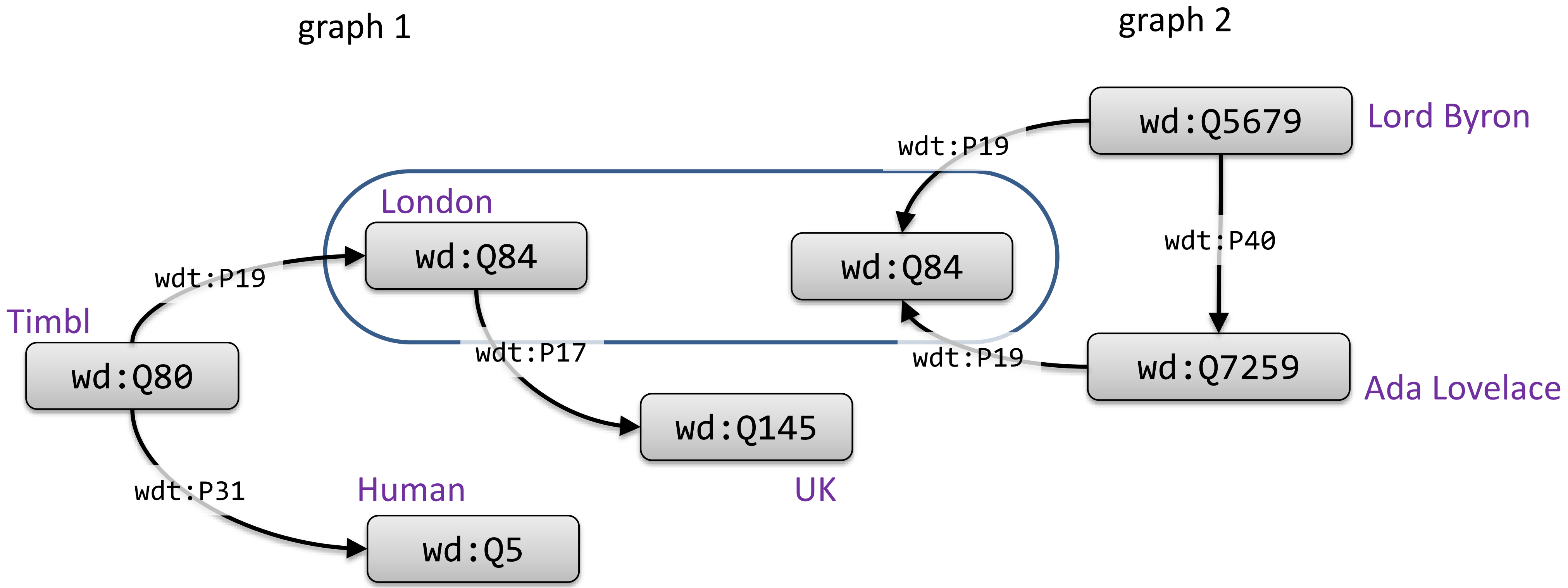
Namespaces simplification



RDF is compositional

RDF graphs can be merged to obtain a bigger RDF graphs

Automatic data integration

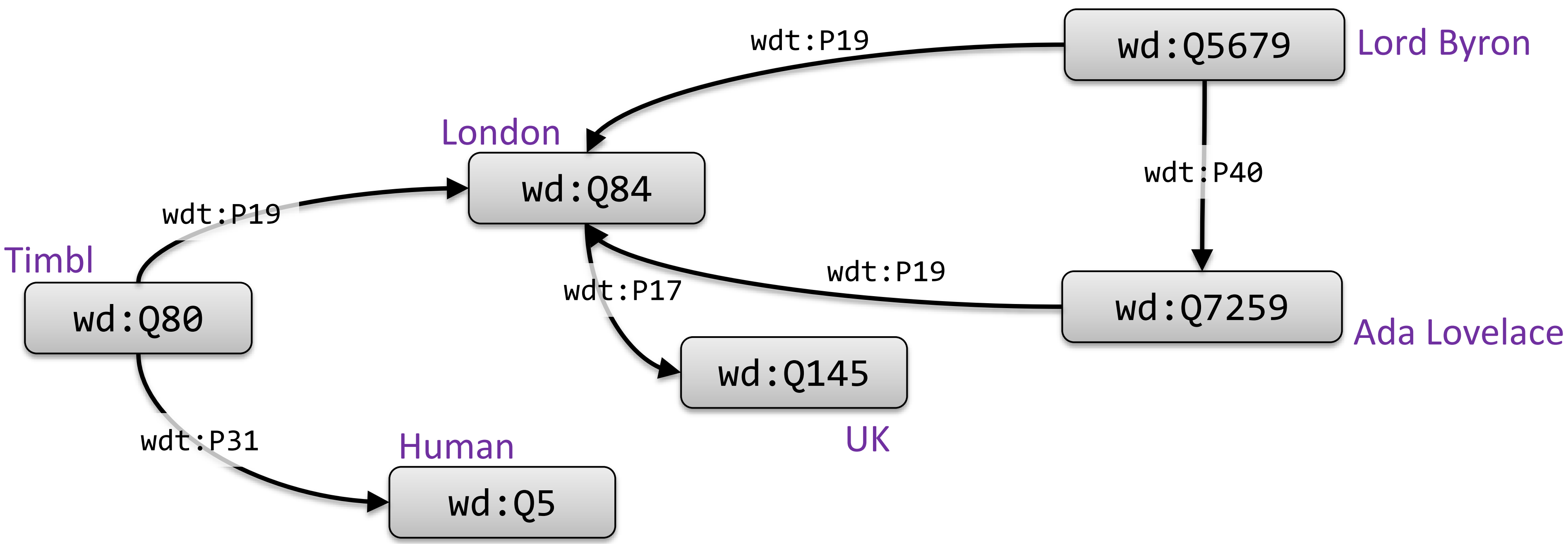


RDF is compositional

RDF graphs can be merged to obtain a bigger RDF graphs

Automatic data integration

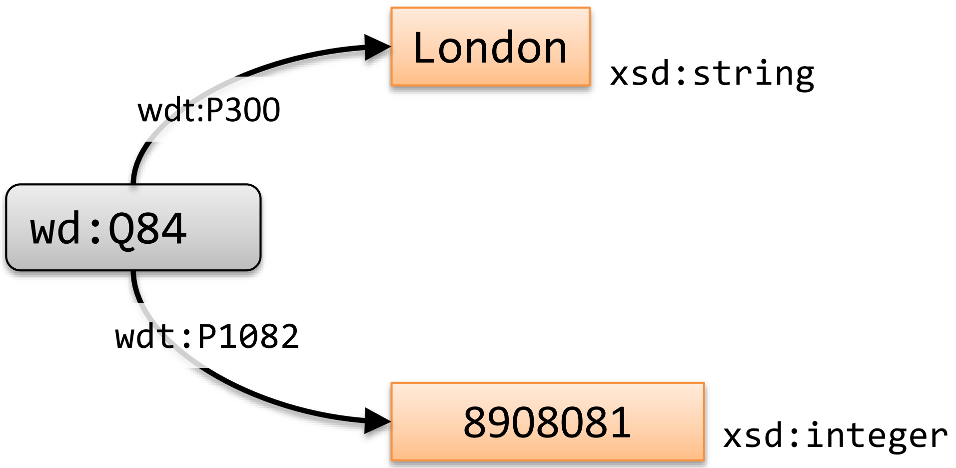
Merged RDF graph



RDF Literals

Objects can also be literals

- Literals contain a lexical form and a datatype
- Typical datatypes = XML Schema primitive datatypes
  - If not specified, a literal has datatype `xsd:string`

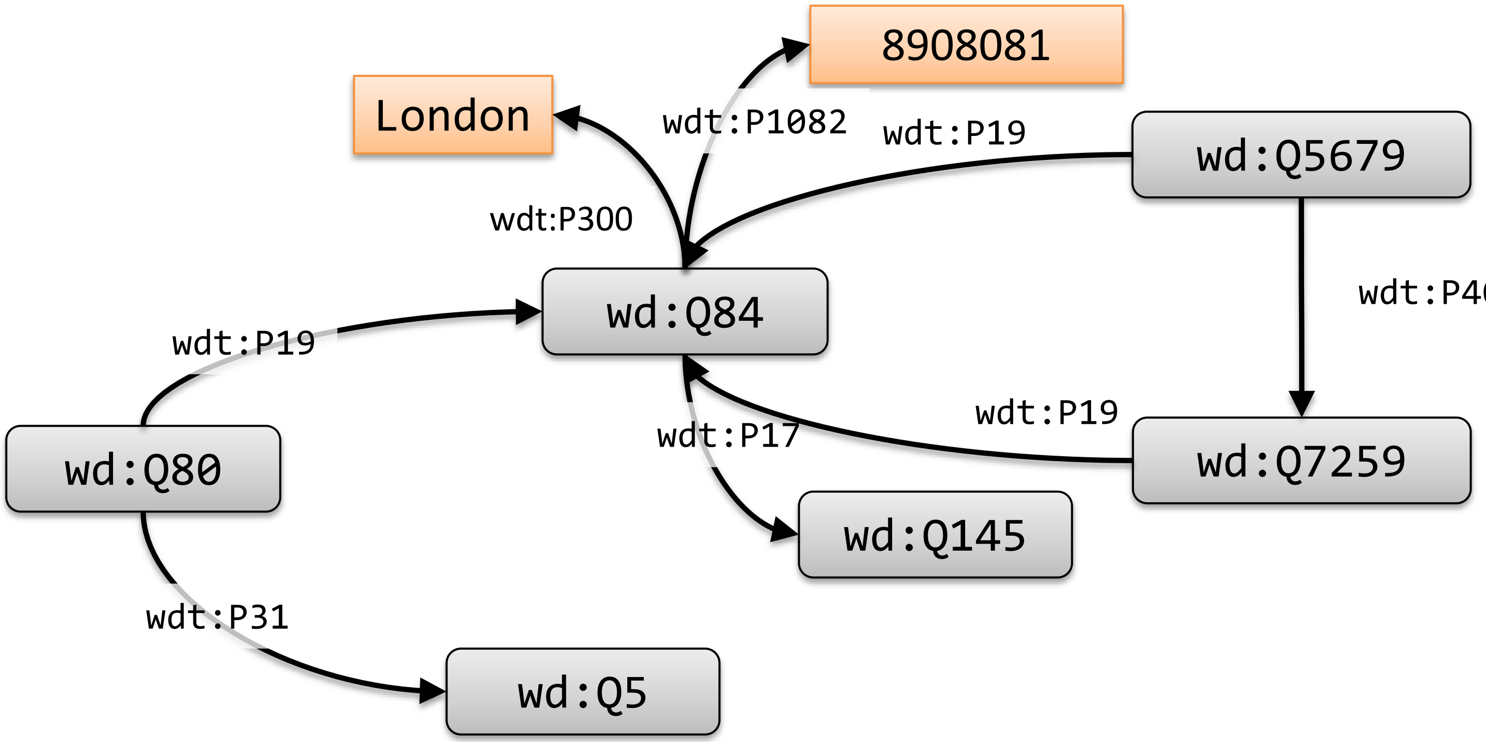


Turtle notation

```
wd:Q84 wd:P300   "GB-LND" ;
wd:Q84 wdt:P1082 "8908081"^^xsd:integer .
```

Remember...RDF is compositional

Merging previous data



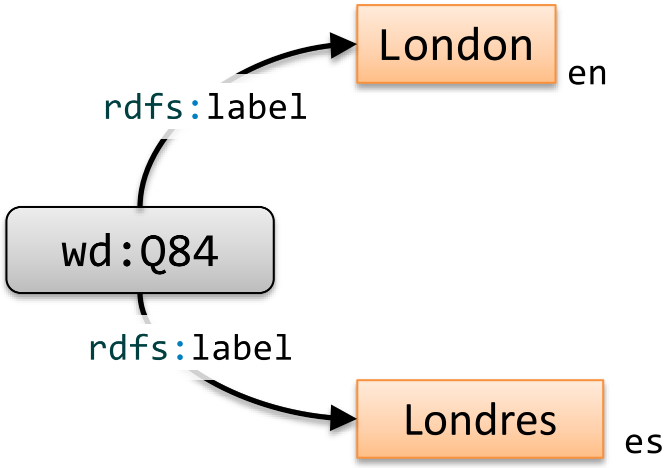

```
prefix wd: <http://www.wikidata.org/entity/>
prefix wdt: <http://www.wikidata.org/prop/direct/>

wd:Q80    wdt:P19 wd:Q84 ;
          wdt:P31 wd:Q5 .
wd:Q5679 wdt:P40 wd:Q7259 ;
          wdt:P19 wd:Q84 .
wd:Q7259 wdt:P19 wd:Q84 .
wd:Q84    wdt:P300 "GB-LND" ;
          wdt:P1082 8908081 ;
          wdt:P17 wd:Q145 .
```

https://rdfshape.weso.es/link/16417186264

Language tagged strings

String literals can be qualified by a language tag

They have datatype `rdfs:langString`

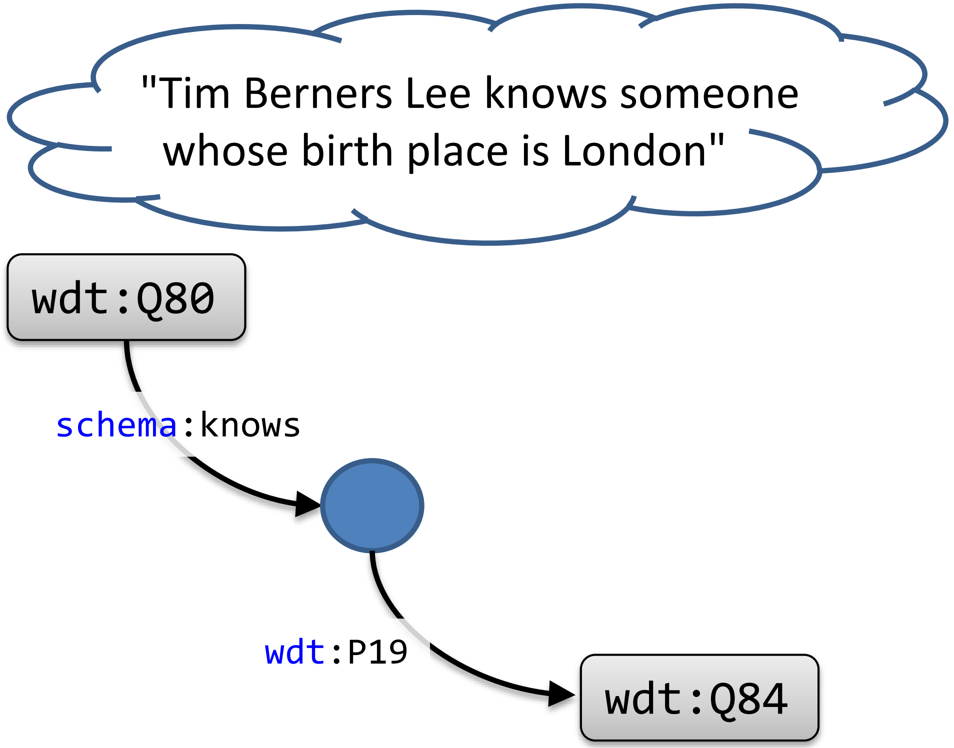


Turtle notation

```
wd:Q84 rdfs:label "London"@en  ;
       rdfs:label "Londres"@es .
```

Blank nodes

Subjects and objects can also be Blank nodes



Turtle notation with local identifier

```
wd:Q80 schema:knows _:x .
_:x    wdt:P19      wd:Q84 .
```

Turtle notation with square brackets

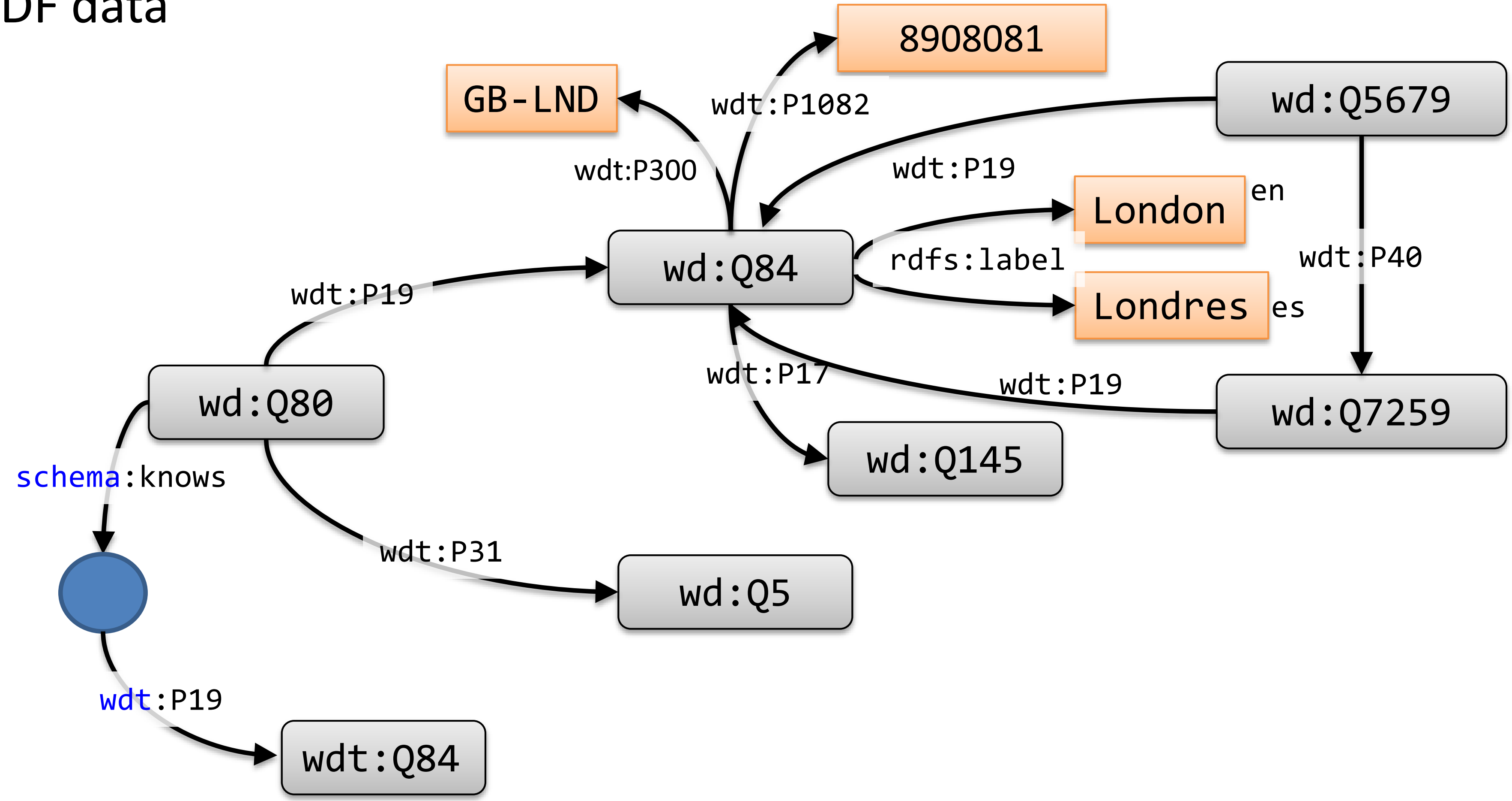
```
wd:Q80 schema:knows [ wdt:P19 wd:Q84 ] .
```

Mathematical meaning:

$\exists x(\text{schema:knows}(\text{wd:Q80}, x) \wedge \text{wdt:P19}(x, \text{wdt:Q84}))$

RDF data model

Example of RDF data

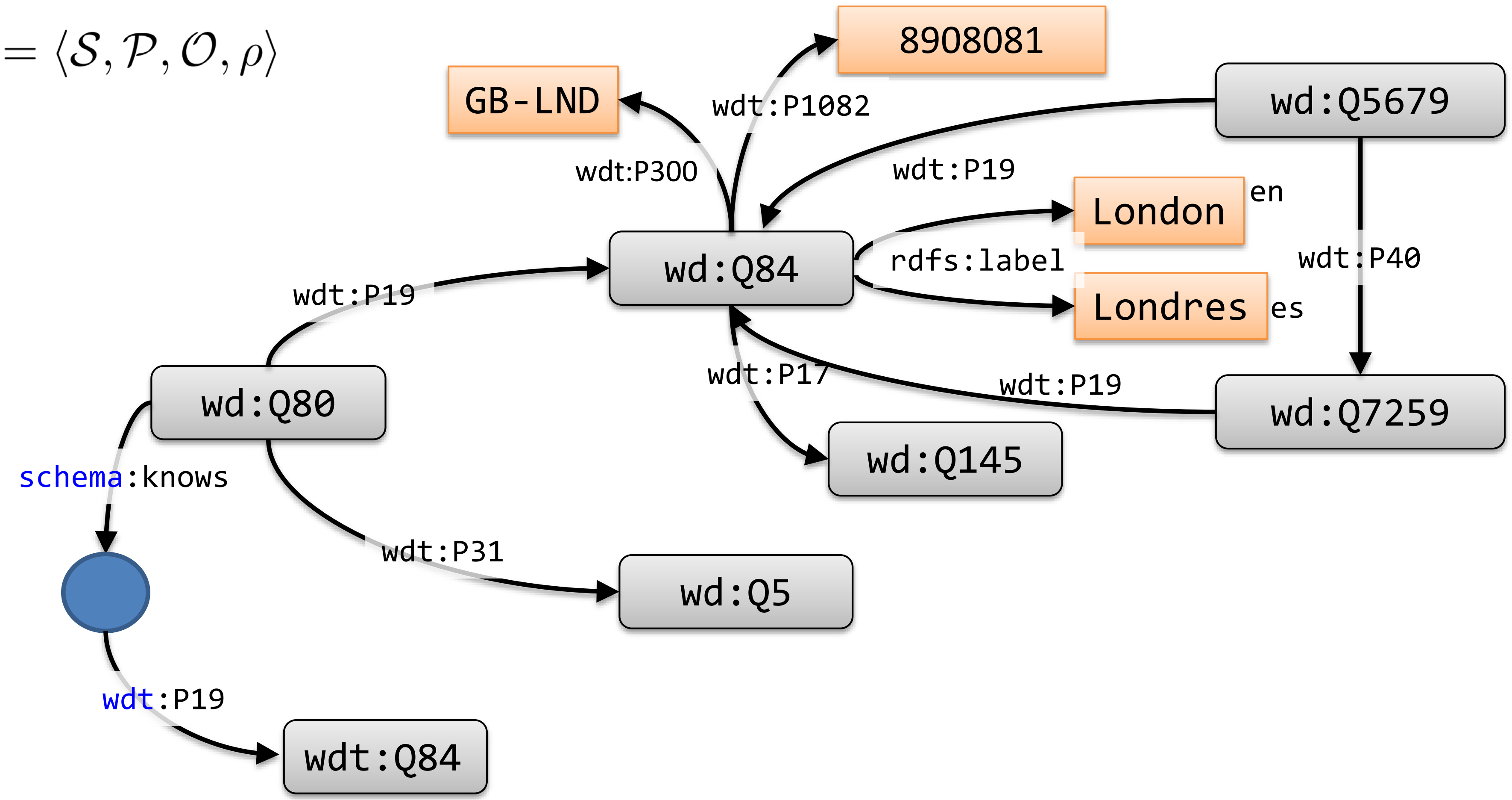


3 types of nodes
IRIs
Blank nodes
Literals

Subjects: URIs or Blank nodes
Objects: URIs, Blank nodes or literals
Predicates always URIs

Formal definition of RDF data model

Given a set of IRIs $\mathcal{I}$,
a set of blank nodes $\mathcal{B}$
and a set of literals Lit
an *RDF graph* is a tuple $\mathcal{G} = \langle \mathcal{S}, \mathcal{P}, \mathcal{O}, \rho \rangle$
where
$\mathcal{S} = \mathcal{I} \cup \mathcal{B}$,
$\mathcal{P} = \mathcal{I}$,
$\mathcal{O} = \mathcal{I} \cup \mathcal{B} \cup Lit$
$\rho \subseteq \mathcal{S} \times \mathcal{P} \times \mathcal{O}$



3 types of nodes
IRIs
Blank nodes
Literals

Subjects: URIs or Blank nodes
Objects: URIs, Blank nodes or literals
Predicates always URIs

...and that's all about the RDF data model

The RDF Data model is very simple

Simple
is
better

Wikibase data model and RDF

2 different data models

Wikibase

- Intial goal: support Wikipedia
- Collaborative model based on MediaWiki
- Combines 2 models
  - Document centric (MediaWiki
  - Graph model (statements)
    - Statements can have qualifiers & references

RDF

- Initial goal: Knowledge representation
- Basis for Semantic Web
- Resources = URIs
- Graph based model
- Graph = Set of triples

Wikibase data model

Described in https://www.mediawiki.org/wiki/Wikibase/DataModel

Entities

- Items (Q..), Properties (P..), Lexemes (L..)
- Each entity has:
- - Labels, descriptions, aliases
- - List of statements (Property-values)
- - Each statement can have qualifiers and references

Built-in data values

- Examples: strings, numbers, dates, time-values, geo-coordinates, ...

Example

Multilingual labels, descriptions and aliases

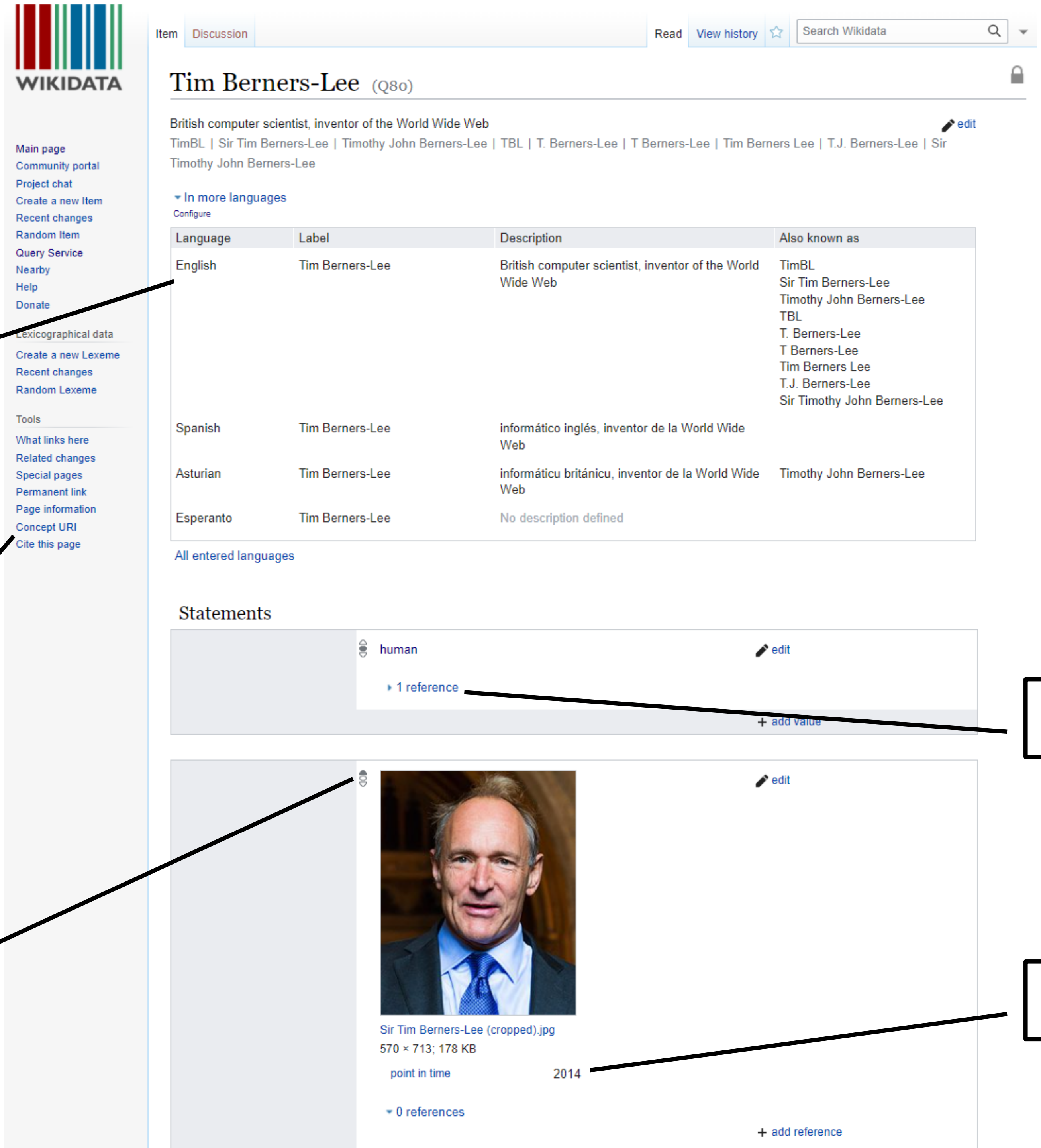
Concept URI

http://www.wikidata.org/entity/Q80

Rank

Hidden reference

Qualifier

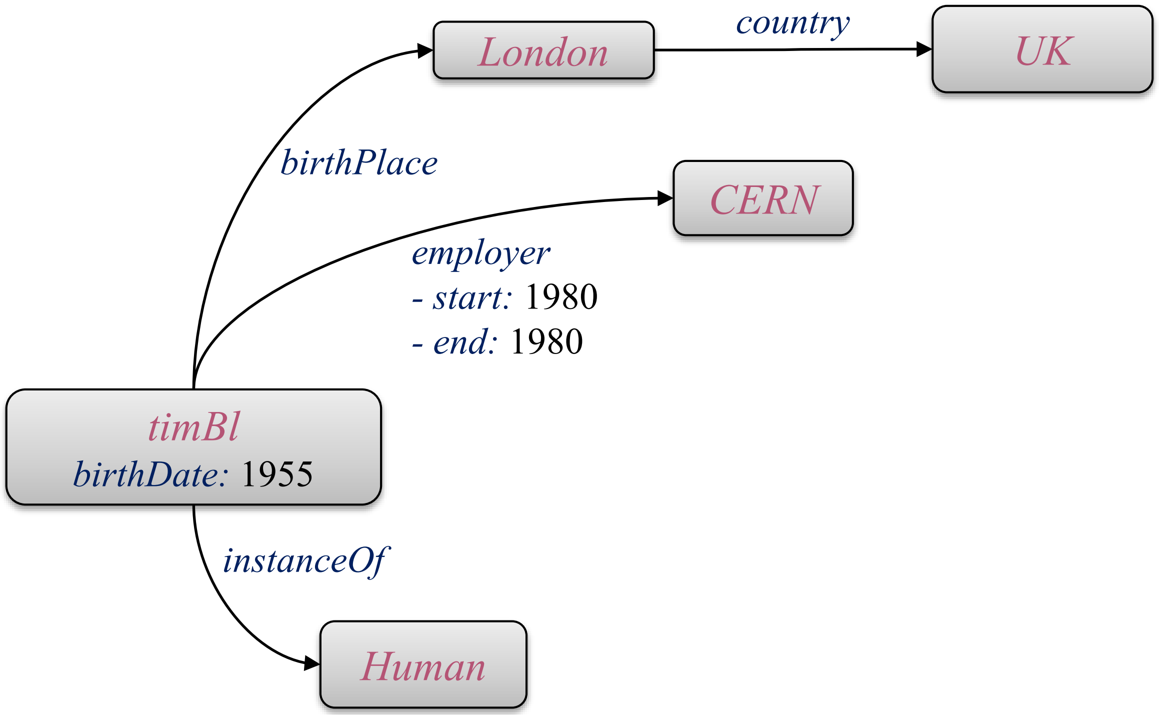


Wikibase graphs

Wikibase graph model similar to Property Graphs

Nodes can have a list of property-values

Statements can also have a list of property-values



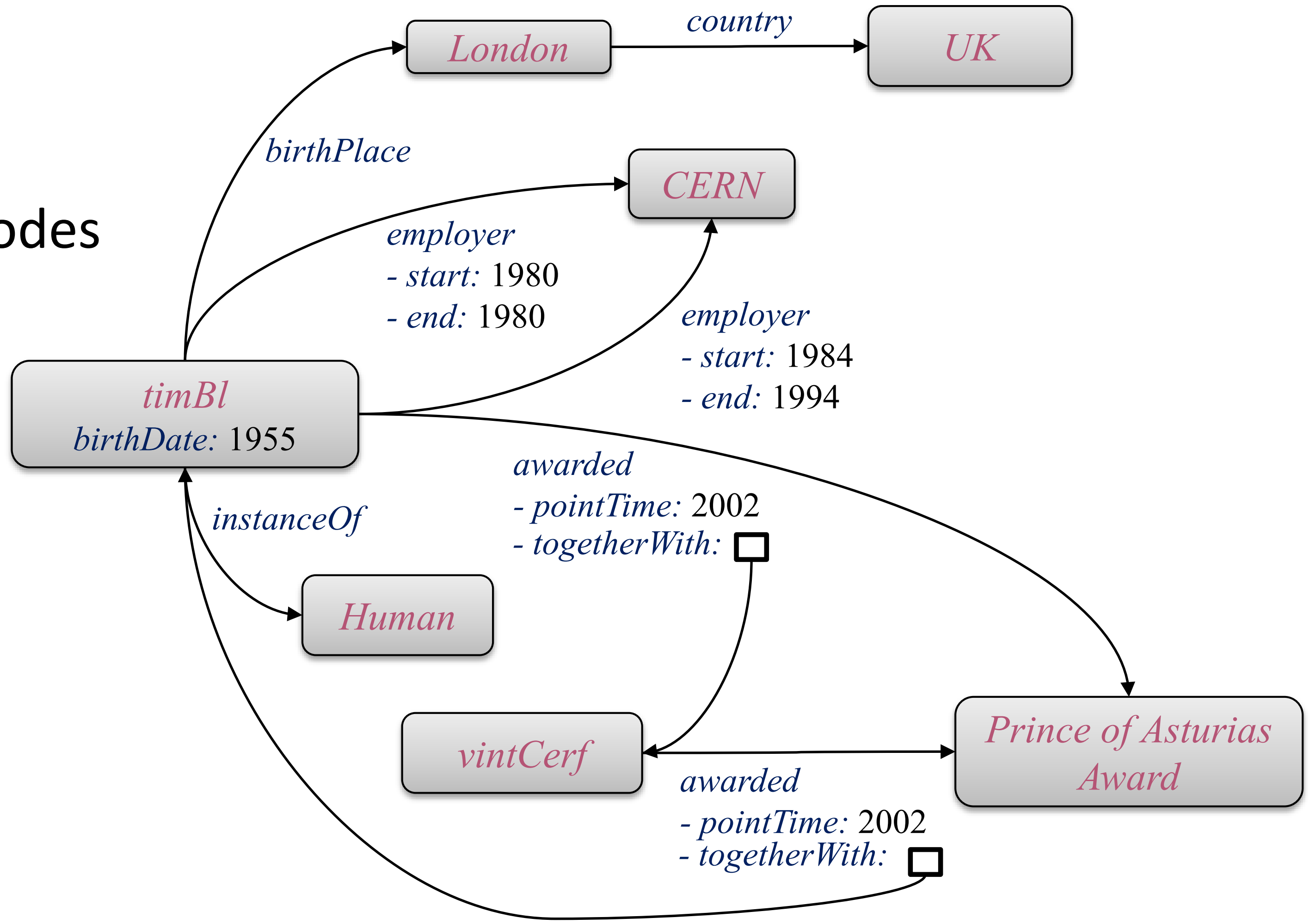
Wikibase graphs

Wikibase graphs = Multigraphs

- It is possible to have more than one statement between the same 2 nodes

Generalize property graphs

- The values can also be nodes



Wikibase ⇝ RDF: prefixes

New namespaces created for Wikidata: wd, wdt, p, ps, pr, psv ...

Reuse popular namespaces: rdf, rdfs, dct, owl, prov, skos, ...

Some popular prefix declarations

wd	http://www.wikidata.org/entity/
wdt	http://www.wikidata.org/prop/direct/
p	http://www.wikidata.org/prop/
ps	http://www.wikidata.org/prop/statement/
pq	http://www.wikidata.org/prop/qualifier/
pr	http://www.wikidata.org/prop/reference/
psv, pqv, prv	http://www.wikidata.org/prop/{statement|qualifier|reference}/value/
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs	http://www.w3.org/2000/01/rdf-schema#
...	...

Wikidata query service assumes those prefix declarations

Wikibase ⇝ RDF: entities

Entity nodes (ex. `wd:Q80`) have type `wikibase:Item`

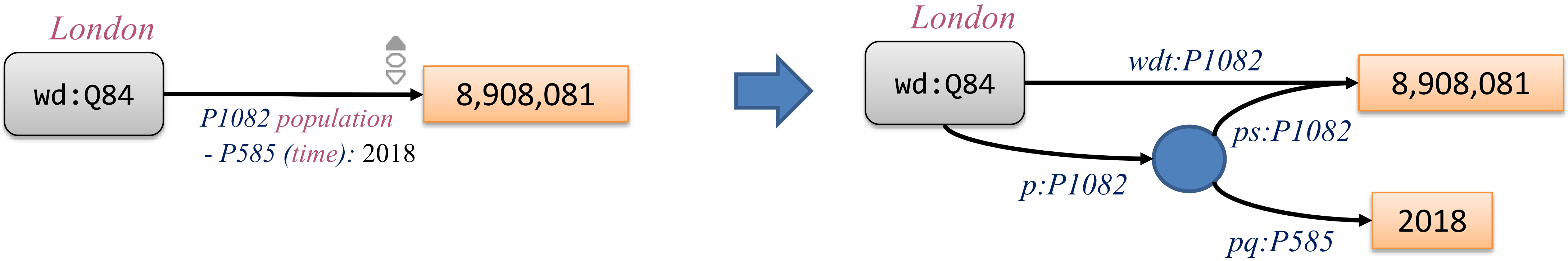
- Labels declared using `rdfs:label`, `skos:prefLabel`, `schema:name`
- Descriptions declared using `schema:description`
- Aliases declared using `skos:altLabel`

```
wd:Q80  rdf:type             wikibase:Item ;
        rdfs:label           "Tim Berners-Lee"@en , "Tim Berners-Lee"@es ;
        schema:description   "British computer scientist, inventor of the World Wide Web"@en ,
                             "informático inglés, inventor de la World Wide Web"@es ;
        schema:name          "Tim Berners-Lee"@en , "Tim Berners-Lee"@es ;
        skos:altLabel        "T Berners-Lee"@en , "Sir Timothy John Berners-Lee"@en ;
        skos:prefLabel       "Tim Berners-Lee"@en , "Tim Berners-Lee"@es
        ...
```

Wikibase ⇝ RDF: statements

Statements have 2 possibilities

- Truthy statements: best non-deprecated rank for a property
- Full statements: contain all data about a statement



Wikibase ⇝ RDF: statements

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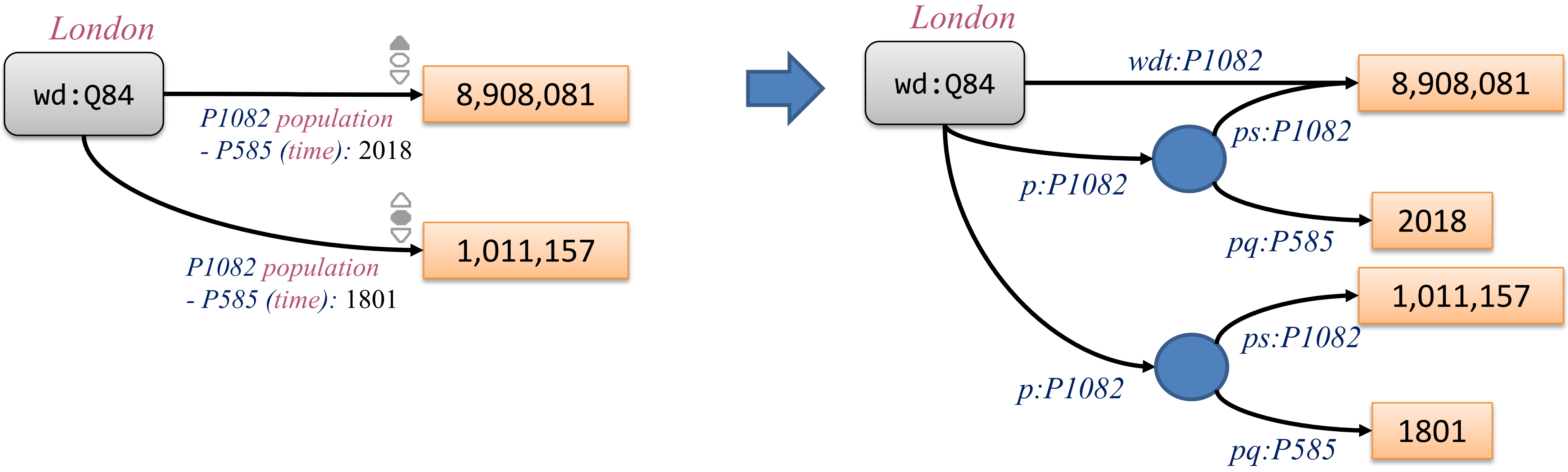
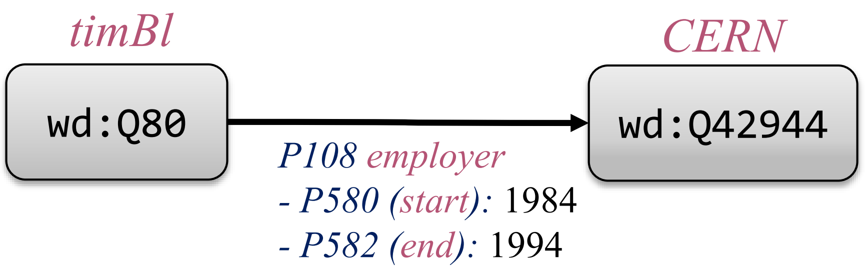


Wikibase ⇝ RDF: qualifiers

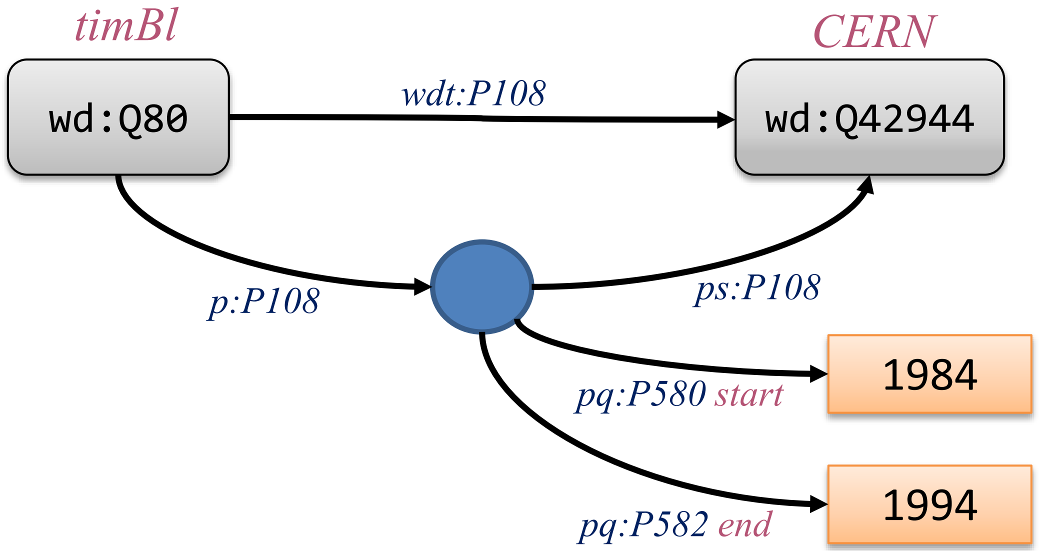
Qualifiers = statements about statements

RDF reification can be used for that

- Different RDF reification alternatives
- Wikibase approach to reification uses auxiliary nodes



Wikibase

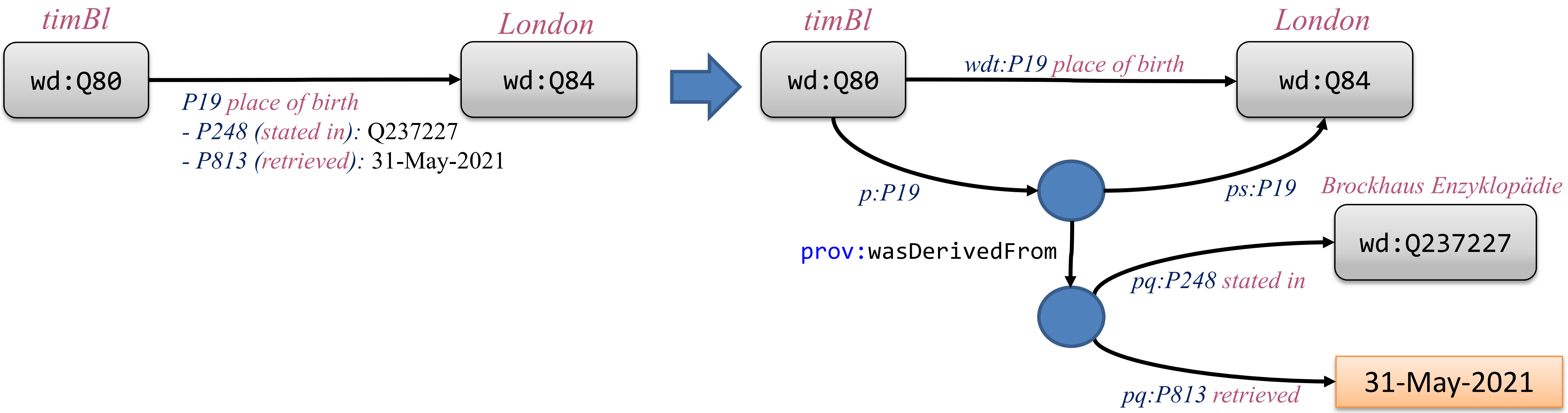


RDF

Wikibase ⇝ RDF: references

References = similar to qualifiers

Adds a new node that represents the provenance information

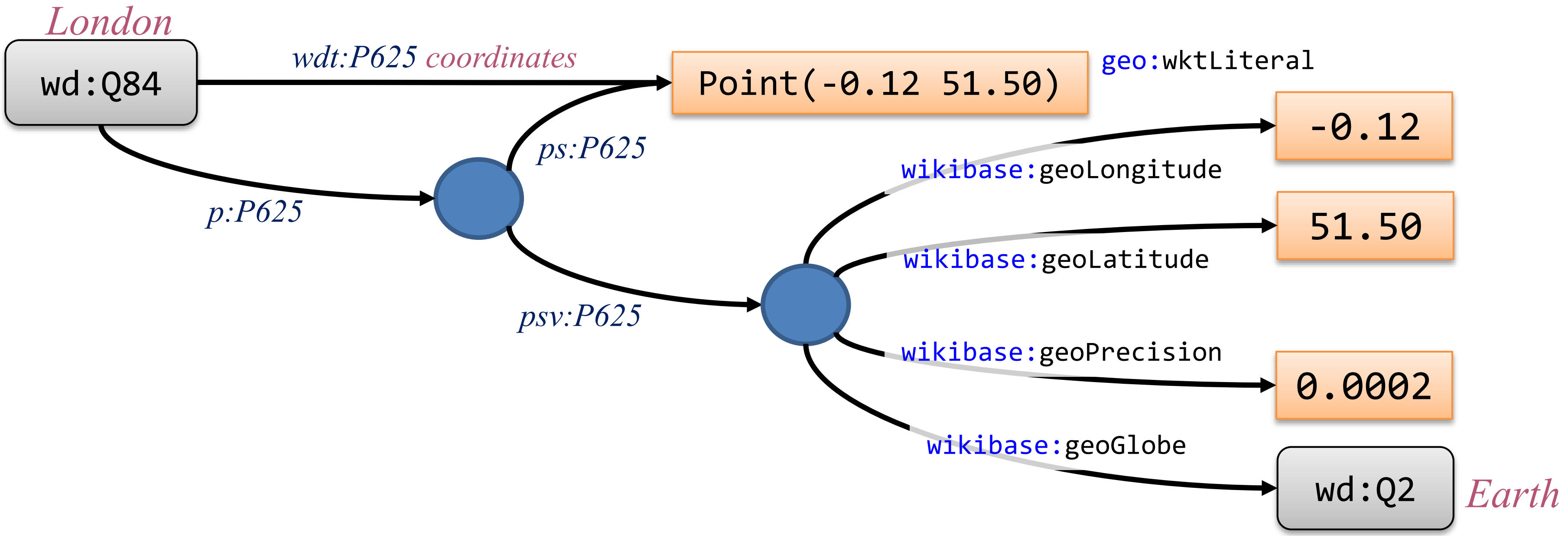


Wikibase ⇝ RDF: values

Values represented as simple and full values

- Simple values = literals or URIs
- Full values include more information

Example London's coordinates:



Wikibase ⇝ RDF: other features

Normalized values

Special values: Some values, NoValues

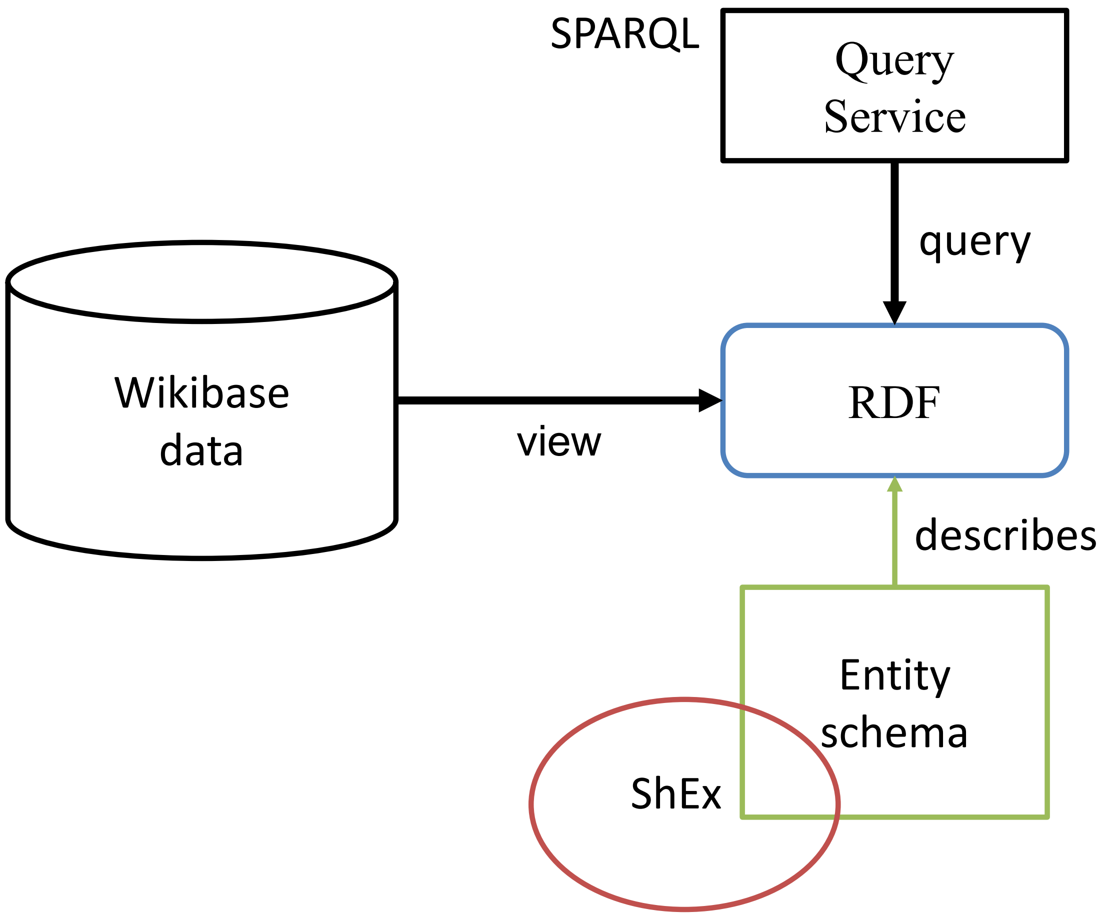
Sitelinks

Redirects

More information: https://www.mediawiki.org/wiki/Wikibase/Indexing/RDF_Dump_Format

Wikibase, RDF and ShEx

Overview



Introduction to Shape Expressions

ShEx

ShEx (Shape Expressions Language)

Goal: RDF validation & description

Design objectives: High level, concise, human-readable, machine processable language

Syntax inspired by SPARQL, Turtle

Semantics inspired by RelaxNG

Official info: http://shex.io

ShEx as a language

Language based approach

- ShEx = domain specific language for RDF validation
- Specification: http://shex.io/shex-semantics/
- Primer: http://shex.io/shex-primer
- Different serializations:
  - ShExC (Compact syntax)
  - JSON-LD (ShExJ)
  - RDF obtained from JSON-LD (ShExR)

Short history of ShEx

2013 - RDF Validation Workshop

- Conclusions: "*SPARQL queries cannot easily be inspected and understood…*"
  - Need of a higher level, concise language
  - Agreement on the term "Shape"

2014 First proposal of Shape Expressions (ShEx 1.0)

2014 - Data Shapes Working Group chartered

- Mutual influence between SHACL & ShEx

2017 - ShEx Community Group - ShEx 2.0

2018 - ShEx 2.1

ShEx implementations and demos

Implementations:

- shex.js: Javascript
- Apache Jena ShEx: Java
- shex-s: Scala (Jena/RDF4j)
- PyShEx: Python
- shex-java: Java
- Ruby-ShEx: Ruby
- ShEx-ex: Elixir

Online demos & playgrounds

- ShEx-simple
- RDFShape
- ShEx-Java
- ShExValidata
- Wikishape

Simple example

Prefix declarations as in Turtle/SPARQL

```
prefix schema: <http://schema.org/>
prefix xsd:    <http://www.w3.org/2001/XMLSchema#>

<User> IRI {
 schema:name  xsd:string   ;
 schema:knows @<User>     *
}
```

Nodes conforming to `<User>` shape must:

- Be IRIs
- Have exactly one `schema:name` with a value of type `xsd:string`
- Have zero or more `schema:knows` whose values conform to <User>

RDF Validation using ShEx

Schema

```
<User> IRI {
 schema:name  xsd:string  ;
 schema:knows @<User>     *
}
```

Shape map

```
:alice@<User>✓
:bob  @<User>✓
:carol@<User>✗
:dave @<User>✗
:emily@<User>✗
:frank@<User>✓
:grace@<User>✗
```

Try it (RDFShape): https://goo.gl/97bYdv
Try it (ShExDemo): https://goo.gl/Y8hBsW

Data

```
:alice schema:name  "Alice" ;
       schema:knows :alice  .

:bob   schema:knows :alice ;
       schema:name  "Robert".

:carol schema:name   "Carol", "Carole" .

:dave  schema:name   234 .

:emily foaf:name     "Emily" .

:frank schema:name "Frank" ;
       schema:email <mailto:frank@example.org> ;
       schema:knows :alice, :bob .

:grace schema:name "Grace" ;
       schema:knows :alice, _:1 .

_:1 schema:name  "Unknown" .
```

Validation process

Input: RDF data, ShEx schema, Shape map
Output: Result shape map

ShEx Schema

```
:User {
 schema:name  xsd:string ;
 schema:knows @:User *
}
```

Shape map

```
:alice@:User, :bob@:User, :carol@:User
```

RDF data

```
:alice schema:name  "Alice" ;
       schema:knows :alice  .

:bob   schema:knows :alice ;
       schema:name  "Robert".

:carol schema:name   "Carol", "Carole" .
```

ShEx Validator

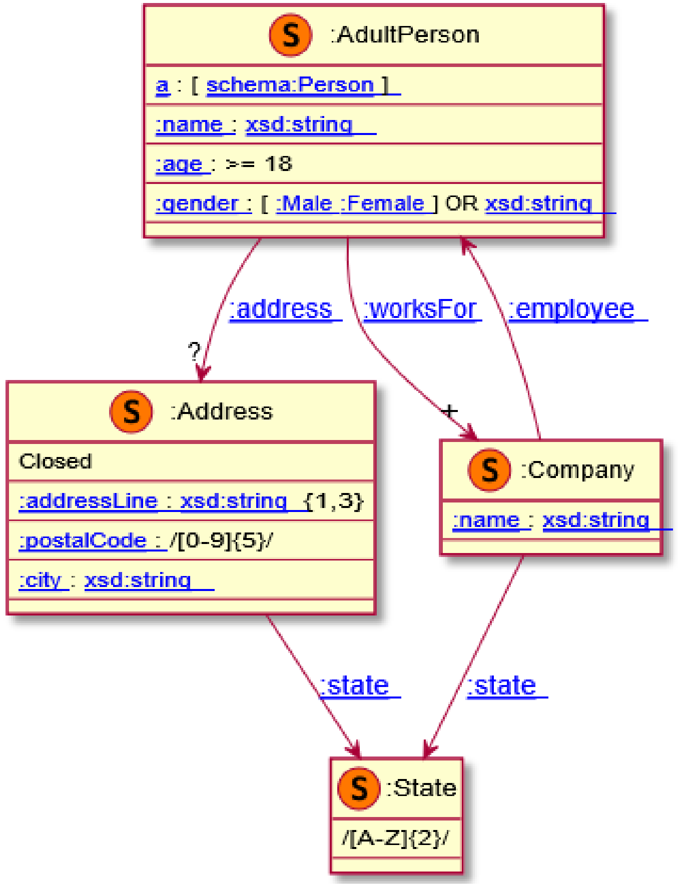
Result shape map

```
:alice@:User,
:bob@:User,
:carol@!:User
```

Example with more ShEx features

```
:AdultPerson EXTRA rdf:type {
 rdf:type    [ schema:Person ]            ;
 :name       xsd:string                   ;
 :age        MinInclusive 18              ;
 :gender     [:Male :Female] OR xsd:string ;
 :address    @:Address ?                  ;
 :worksFor   @:Company +
}
:Address CLOSED {
 :addressLine xsd:string {1,3}
 :postalCode  /[0-9]{5}/
 :state       @:State
 :city        xsd:string
}
:Company {
 :name     xsd:string
 :state    @:State
 :employee @:AdultPerson *
}
:State   /[A-Z]{2}/
```

```
:alice rdf:type :Student, schema:Person ;
 :name       "Alice" ;
 :age        20 ;
 :gender     :Male ;
 :address    [
  :addressLine  "Bancroft Way" ;
  :city         "Berkeley" ;
  :postalCode   "55123" ;
  :state        "CA"
 ] ;
 :worksFor  [
  :name       "Company" ;
  :state      "CA"      ;
  :employee   :alice
] .
```



Try it: https://tinyurl.com/yd5hp9z4

ShExC - Compact syntax

BNF Grammar: http://shex.io/shex-semantics/#shexc

Shares terms with Turtle and SPARQL

- Prefix declarations
- Comments starting by #
- a keyword = rdf:type
- Keywords aren't case sensitive (MinInclusive = MININCLUSIVE)

Shape Labels can be URIs or BlankNodes

ShEx-Json

JSON-LD serialization for Shape Expressions and validation results

```
prefix schema: <http://schema.org/>
prefix xsd:    <http://www.w3.org/2001/XMLSchema#>
base   <http://example.com/>

<User> {
  schema:name  xsd:string ;
}
```

equivalent

```
{ "type" : "Schema",
  "@context" : "http://www.w3.org/ns/shex.jsonld",
  "shapes" :[{"type" : "Shape",
    "id" : "http://a.example/UserShape",
    "expression" : {
    "type" : "TripleConstraint",
    "predicate" : "http://schema.org/name",
    "valueExpr" : { "type" : "NodeConstraint",
      "datatype" : "http://www.w3.org/2001/XMLSchema#string"
     }
   }
  }]
}
```

Some definitions

Schema = set of Shape Expressions

Shape Expression = labeled pattern

```
<label> {
  ...pattern...
}
```

Shape
Label

Shape
Expression

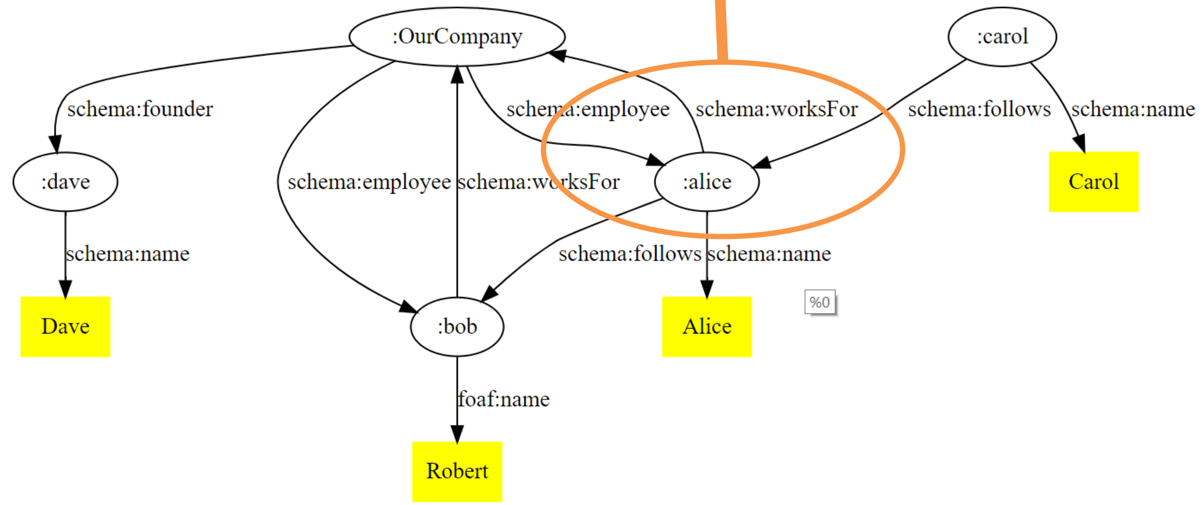
```
<UserShape> {
  schema:name  xsd:string
}
```

Focus Node and Neighborhood

Focus Node = node that is being validated

```
:alice      schema:name     "Alice";
            schema:follows  :bob;
            schema:worksFor :OurCompany .

:bob        foaf:name       "Robert" ;
            schema:worksFor :OurCompany .

:carol      schema:name     "Carol" ;
            schema:follows  :alice .

:dave       schema:name      "Dave" .

:OurCompany schema:founder :dave ;
            schema:employee :alice, :bob .
```

```
Neighbourhood of :alice = {
  (:alice,      schema:name,      "Alice")
  (:alice,      schema:follows,   :bob),
  (:alice,      schema:worksFor,  :OurCompany),
  (:carol,      schema:follows,   :alice),
  (:OurCompany, schema:employee,  :alice)
}
```



Shape maps

Shape maps declare which node/shape pairs are selected

- They declare the queries that ShEx engines solve
  - Example: Does `:alice` conform to `<User>` ?
    - `:alice@<User>`
  - Example: Do all subjects of `schema:knows` conform to `<User>` ?
    - `{FOCUS schema:knows _ }@<User>`

3 types of shape maps:

- Query shape maps: Input shape maps
- Fixed shape maps: Simple pairs of node/shape
- Result shape maps: Shape maps generated by the validation process

Shape map resolver

Converts query shape maps to fixed shape maps

Query shape map

```
{FOCUS schema:worksFor _ }@:User
{FOCUS rdf:type schema:Person}@:User,
{_ schema:worksFor FOCUS }@:Company
```

ShapeMap Resolver

Fixed shape map

```
:alice@:User,
:bob@:User,
:carol@:User,
:c1@:Company,
:c2@:Company,
```

RDF Graph

```
:alice a :User .

:bob   schema:worksFor :c1,
                       :c2 .

:carol a schema:Person ;
       schema:worksFor :c1 .
```

ShEx validator

Input: schema, rdf data and fixed shape map, Output: result shape map

ShEx Schema

```
:User {
 schema:name  xsd:string ;
 schema:knows @:User*
}
```

Fixed shape map

```
:alice@:User,
:bob  @:User
```

ShEx Validator

Result Shape map

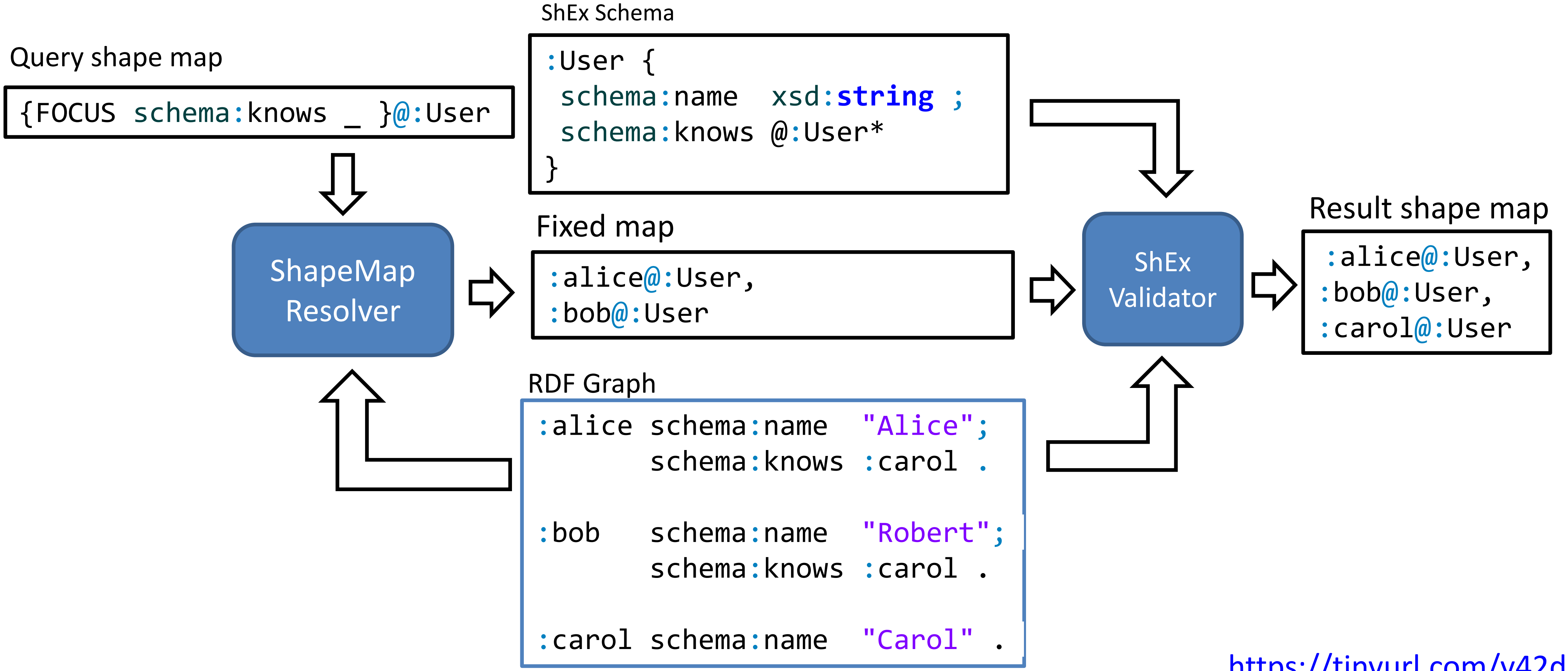
```
:alice@:User,
:bob@:User,
:carol@:User
```

RDF data

```
:alice schema:name  "Alice";
       schema:knows :carol .

:bob   schema:name  "Robert" .

:carol schema:name  "Carol" .
```

Validation process

2 stages: 1) ShapeMap resolver
2) ShEx validator



https://tinyurl.com/y42dclaa

Query maps

A simple language that can be used to generate fixed shape maps

Specification: http://shex.io/shape-map/

Examples:

`:alice@:User`	Checks `:alice` as `:User`
`:alice@:User, :cmp@:Company`	Checks `:alice` as `:User` and `:cmp` as `:Company`
`{_ schema:knows FOCUS }@:User`	Checks nodes who `schema:know` some node
`{FOCUS schema:knows _ }@:User`	Checks nodes who are `schema:known` by some node

`SPARQL """ prefix schema: <http://schema.org/>`
 	
`select ?node where {`
	The same as before
	Any SPARQL query can be used to obtain focus nodes

Node constraints

Constraints over an RDF node

Node constraints

```
:User {
 schema:name        xsd:string ;
 schema:birthDate   xsd:date? ;
 schema:gender      [schema:Male schema:Female] OR xsd:string;
 schema:knows       IRI @:User*
}
```

Node constraints

Triple constraints

Constraints about the incoming/outgoing arcs of a node

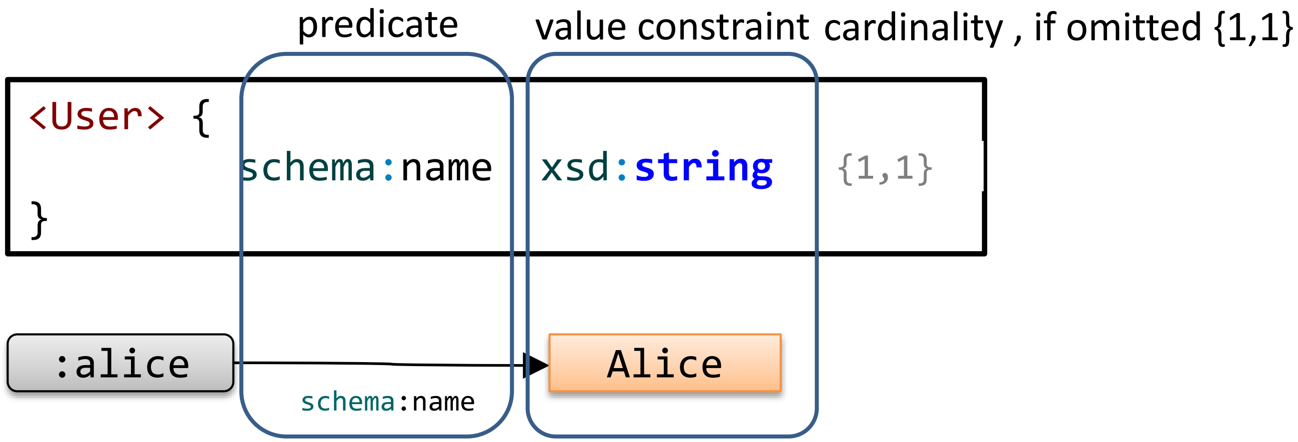
```
:User {
 schema:name        xsd:string ;
 schema:birthDate   xsd:date ? ;
 schema:gender      [schema:Male schema:Female] OR xsd:string;
 schema:knows       IRI @:User *
}
```

Triple constraints

Triple constraints

A basic expression consists of a Triple Constraint

Triple constraint ≈ predicate + value constraint + cardinality



Shape expressions

Labelled rules

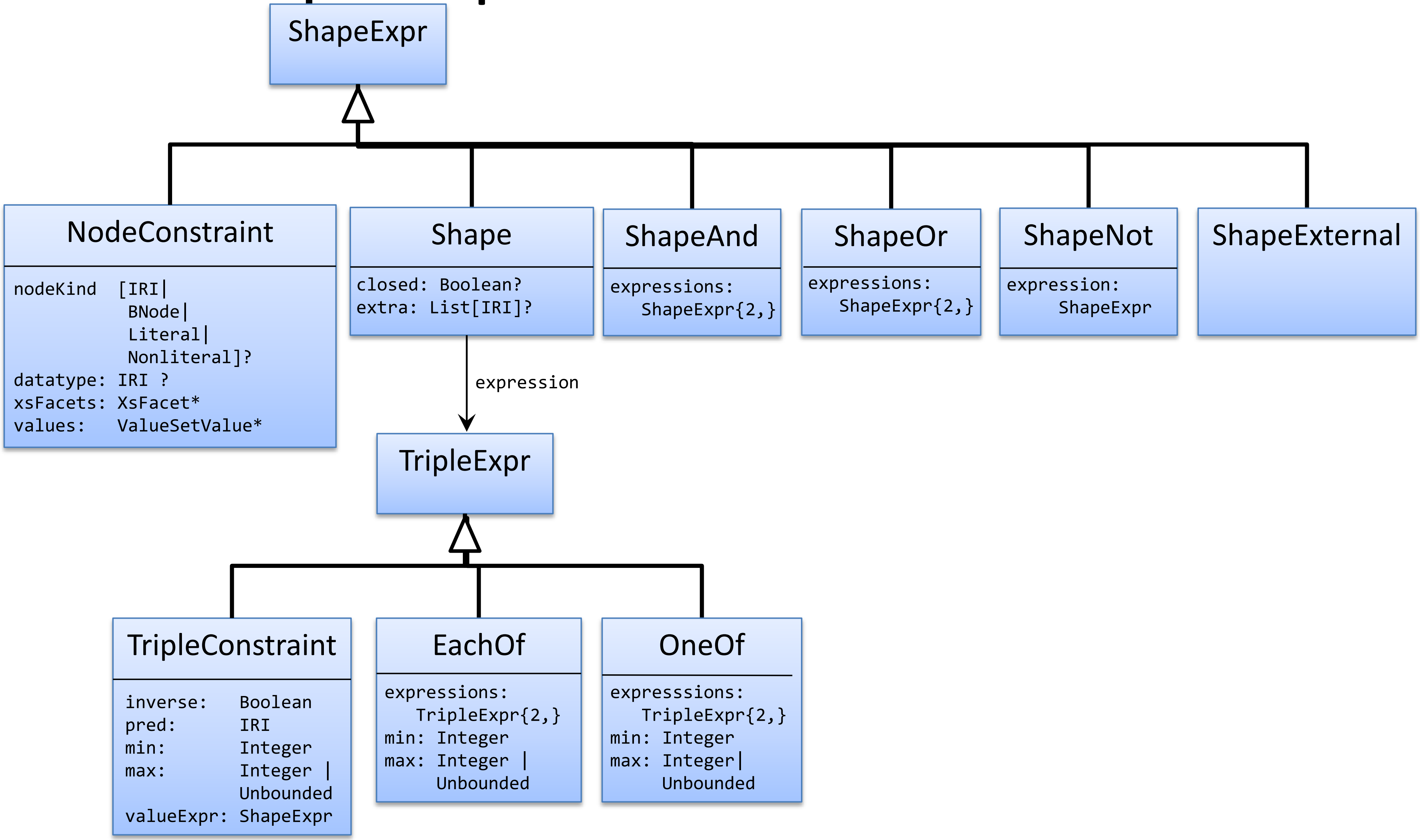
Shape expression label

Shape expression

Triple expression

```
:User {
  schema:name        xsd:string ;
  schema:birthDate   xsd:date ? ;
  schema:gender      [schema:Male schema:Female] OR xsd:string;
  schema:knows       IRI @:User *
}
```

Structure of Shape Expressions



Simple expressions and grouping

The each-of operator ; combines triple expressions

- Unordered sequence

```
:User {
 schema:name   xsd:string  ;
 foaf:age      xsd:integer ;
 schema:email  xsd:string  ;
}
```

```
:alice schema:name  "Alice";
       foaf:age     10 ;
       schema:email "alice@example.org" .

:bob   schema:name  "Robert Smith" ;                  ☹
       foaf:age     45 ;
       schema:email <mailto:bob@example.org> .

:carol schema:name   "Carol" ;                        ☹
       foaf:age      56, 66 ;
       schema:email  "carol@example.org" .
```

Repeated properties

A repeated property indicates that **each of** the expressions must be satisfied

```
<User> {
 schema:name   xsd:string;
 schema:parent @<Male>;
 schema:parent @<Female>
}

<Male> {
 schema:gender [schema:Male ]
}

<Female> {
 schema:gender [schema:Female]
}
```

Means that <User> must have two parents, one male and another female

```
:alice schema:name   "Alice" ;
       schema:parent :bob, :carol .

:bob   schema:name   "Bob" ;
       schema:gender schema:Male .

:carol schema:name   "Carol" ;
       schema:gender schema:Female .
```

Try it (RDFShape): https://goo.gl/d3KWPJ

Cardinalities

Inspired by regular expressions

- Traditional operators: *, +, ?
- ...plus cardinalities {m, n}
- If omitted {1,1} = default cardinality

`*`	0 or more
`+`	1 or more
`?`	0 or 1
`{m}`	m repetitions
`{m,n}`	Between m and n repetitions
`{m,}`	m or more repetitions

Example with cardinalities

```
<User> {
 schema:name xsd:string         ;
 schema:worksFor @<Company>    ? ;
 schema:follows  @<User>       *
}

<Company> {
 schema:founder  @<User>       ? ;
 schema:employee @<User> {1,100}
}
```

```
:alice      schema:name     "Alice";
            schema:follows  :bob;
            schema:worksFor :OurCompany .

:bob        schema:name     "Robert" ;
            schema:worksFor :OurCompany .

:carol      schema:name     "Carol" ;
            schema:follows  :alice .

:dave       schema:name      "Dave" .

:OurCompany schema:founder :dave ;
            schema:employee :alice, :bob .
```

Try it: https://goo.gl/ddQHPo

Choices - OneOf

The one-of operator | represents alternatives (either one or the other)

```
:User {
  schema:name  xsd:string ;
| schema:givenName xsd:string + ;
  schema:lastName  xsd:string
}
```

```
:alice schema:name      "Alice Cooper" .

:bob   schema:givenName "Bob", "Robert" ;
       schema:lastName  "Smith" .

:carol schema:name      "Carol King" ;  ☹
       schema:givenName "Carol" ;
       schema:lastName  "King" .

:dave  foaf:name        "Dave" .        ☹
```

Try it (RDFShape): https://goo.gl/hCvyRN

Node constraints

Type	Example	Description
Anything	.	The value can be anything
Datatype	xsd:string	Matches a literal with datatype xsd:string
Kind	IRI BNode Literal NonLiteral	The object must have that kind
Value set	[:Male :Female]	The value must be :Male or :Female
Reference	@<User>	The value must have shape <User>
Composed with OR AND NOT	xsd:string OR IRI	The value must have datatype xsd:string or be an IRI
IRI Range	foaf:~	The value must start with the IRI associated with foaf
Any except...	- :Checked	Any value except :Checked

No constraint

A dot (.) matches anything ⇒ no constraint on values

```
:User {
 schema:name        . ;
 schema:affiliation . ;
 schema:email       . ;
 schema:birthDate   .
}
```

```
:alice
   schema:name        "Alice";
   schema:affiliation [ schema:name "OurCompany" ] ;
   schema:email       <mailto:alice@example.org> ;
   schema:birthDate   "2010-08-23"^^xsd:date .
```

Try it: https://goo.gl/LNVg4p

Datatypes

Datatypes are directly declared by their URIs

Predefined datatypes from XML Schema:

`xsd:string xsd:integer xsd:date …`

```
:User {
 schema:name      xsd:string;
 schema:birthDate xsd:date
}
```

```
:alice schema:name      "Alice";
       schema:birthDate "2010-08-23"^^xsd:date.

:bob   schema:name      "Robert" ;            ☹
       schema:birthDate "Unknown" .

:carol schema:name      _:unknown ;           ☹
       schema:birthDate 2012 .
```

Try it: https://goo.gl/neVWeC

Facets on Datatypes

It is possible to qualify the datatype with XML Schema facets

See: http://www.w3.org/TR/xmlschema-2/#rf-facets

Facet	Description
MinInclusive, MaxInclusive MinExclusive, MaxExclusive	Constraints on numeric values which declare the min/max value allowed (either included or excluded)
TotalDigits, FractionDigits	Constraints on numeric values which declare the total digits and fraction digits allowed
Length, MinLength, MaxLength	Constraints on string values which declare the length allowed, or the min/max length allowed
/… /	Regular expression pattern

Facets on Datatypes

```
:User {
 schema:name  xsd:string  MaxLength 10 ;
 foaf:age     xsd:integer MinInclusive 1 MaxInclusive 99 ;
 schema:phone xsd:string  /\\d{3}-\\d{3}-\\d{3}/
}
```

```
:alice schema:name  "Alice";
       foaf:age     10 ;
       schema:phone "123-456-555" .

:bob   schema:name  "Robert Smith" ;    ☹
       foaf:age     45 ;
       schema:phone "333-444-555" .

:carol schema:name  "Carol" ;           ☹
       foaf:age     23 ;
       schema:phone "23-456-555" .
```

Try it: https://goo.gl/8KanuJ

Node Kinds

Define the kind of RDF nodes: Literal, IRI, BNode, ...

Value	Description	Examples

`Literal`	Literal values	`"Alice"`
		`"Spain"@en`
		`23`
		`true`

`IRI`	IRIs	`<http://example.org/alice>` `ex:alice`
`BNode`	Blank nodes	`_:1`

`NonLiteral`	Blank nodes or IRIs	`_:1`
		`<http://example.org/alice>`
		`ex:alice`

Example with node kinds

```
:User {
 schema:name    Literal ;
 schema:follows IRI
}
```

```
:alice schema:name    "Alice" ;
       schema:follows :bob .

:bob   schema:name    :Robert ;   ☹
       schema:follows :carol .

:carol schema:name    "Carol" ;   ☹
       schema:follows "Dave"  .
```

Try it: https://goo.gl/B6x2rE

Value sets

The value must be one of the values of a given set

Denoted by [and]

```
:Product {
 schema:color        [ "Red" "Green" "Blue" ] ;
 schema:manufacturer [ :OurCompany :AnotherCompany ]
}
```

```
:x1 schema:color "Red";
    schema:manufacturer :OurCompany .

:x2 schema:color "Cyan" ;
    schema:manufacturer :OurCompany .

:x3 schema:color "Green" ;
    schema:manufacturer :Unknown .
```

☹ ☹

Try it: https://goo.gl/AJ1eQX

Single value sets

Value sets with a single element

- A very common pattern

```
<SpanishProduct> {
 schema:country [ :Spain ]
}

<FrenchProduct> {
 schema:country [ :France ]
}

<VideoGame> {
 a [ :VideoGame ]
}
```

```
:product1 schema:country :Spain .

:product2 schema:country :France .

:product3 a :VideoGame ;
          schema:country :Spain .
```

Note: ShEx doesn't interact with inference

It just checks if there is an `rdf:type` arc

- Inference can be done before/after validating
- It can even be used to validate inference systems

Try it: https://goo.gl/NpZN9n

Language tagged literals

```
:FrenchProduct {
 schema:label [ @fr ]
}

:SpanishProduct {
 schema:label [ @es @es-AR @es-ES ]
}
```

```
:car1 schema:label "Voiture"@fr .    # Passes as  :FrenchProduct

:car2 schema:label "Auto"@es .       # Passes as :SpanishProduct

:car3 schema:label "Carro"@es-AR .   # Passes as  :SpanishProduct

:car4 schema:label "Coche"@es-ES .   # Passes as  :SpanishProduct
```

Shape references

Defines that the value must match another shape

References are marked as @

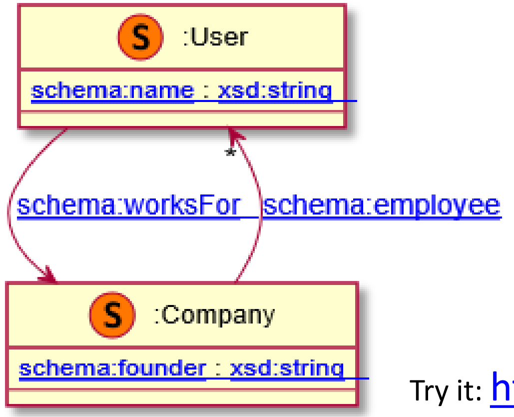
```
:User {
 schema:name xsd:string     ;
 schema:worksFor @:Company
}

:Company {
 schema:founder xsd:string
}
```

```
:alice a :User;
       schema:worksFor :OurCompany .

:bob   a :User;
       schema:worksFor :Another .          ☹

:OurCompany
       schema:name     "OurCompany" .

:Another
       schema:name      23 .               ☹
```

Try it: https://goo.gl/Q3SriH

Recursion and cyclic data models

```
:User {
 schema:name      xsd:string  ;
 schema:worksFor @:Company ;
}

:Company {
 schema:founder  xsd:string  ;
 schema:employee @:User *
}
```

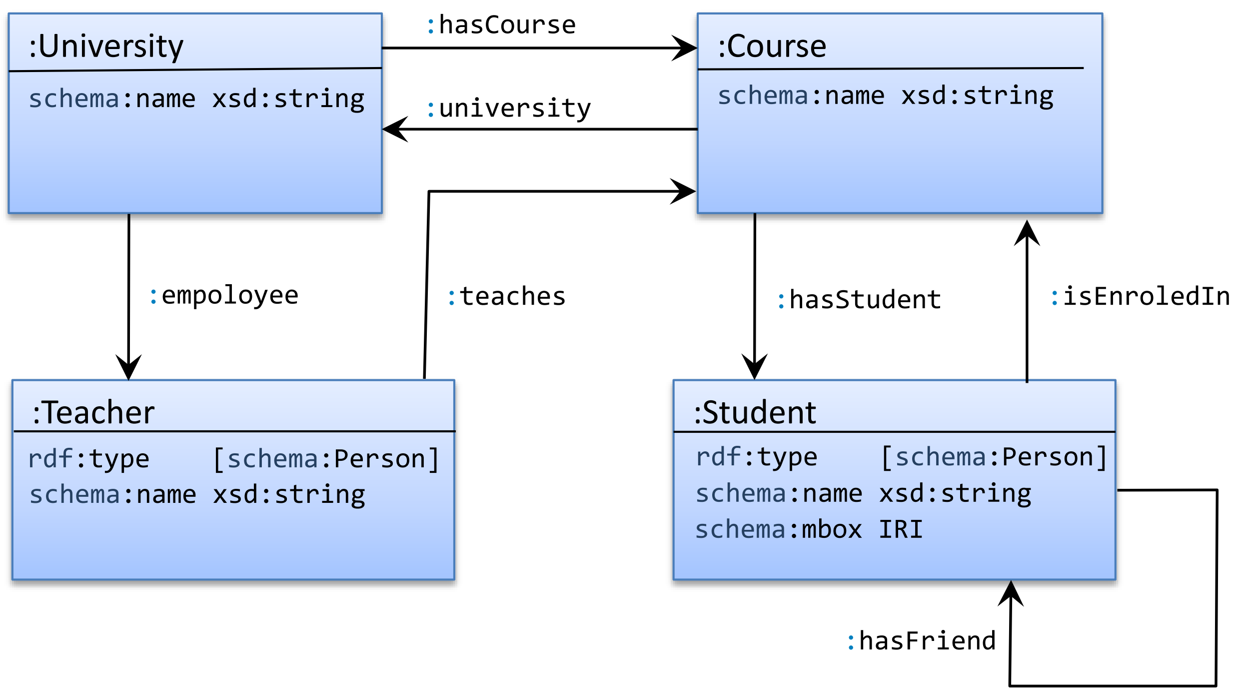



```
:alice    schema:name     "Alice";;
          schema:worksFor :OurCompany .

:bob      schema:name     "Robert";          ☹
          schema:worksFor :Another .

:companyA schema:founder     "Carol";
          schema:employee    :alice .

:companyB schema:founder     "Another" .     ☹
          schema:employee    :unknown .
```

Try it: https://goo.gl/eMNiyR

Exercise

Define a Schema for the following domain model



IRI ranges

`uri:~` represents the set of all URIs that start with stem `uri`

```
prefix codes: <http://example.codes/>

:User {
  :status [ codes:~ ]
}
```

```
prefix codes: <http://example.codes/>
prefix other: <http://other.codes/>

:x1 :status codes:resolved .

:x2 :status other:done .                ☹

:x3 :status <http://example.codes/pending> .
```

Try it: https://goo.gl/EC521J

IRI Range exclusions

The operator - excludes IRIs or IRI ranges from an IRI range

```
prefix codes: <http://example.codes/>

:User {
  :status [
      codes:~ - codes:deleted
  ]
}
```

```
:x1 :status codes:resolved .

:x2 :status other:done.          ☹

:x3 :status <http://example.codes/pending> .

:x4 :status codes:deleted .      ☹
```

Try it: https://goo.gl/pU8u4b

Nested shapes

Syntax simplification to avoid defining two shapes

- Internally, the inner shape is identified using a blank node

```
User {
  schema:name      xsd:string ;
  schema:worksFor _:1
}

_:1 a [ schema:Company ] .
```

≡

```
:User {
  schema:name      xsd:string ;
  schema:worksFor {
    a [ schema:Company ]
  }
}
```

```
:alice schema:name      "Alice" ;
       schema:worksFor :OurCompany .

:OurCompany a schema:Company .
```

Try it (RDFShape): https://goo.gl/2Eoehi

Labeled constraints

`$label` <constraint> associates a constraint to a label

It can later be used as `&label`

```
:User {
 $:name ( schema:name .
        | schema:givenName . ;
          schema:familyName .
        ) ;
 schema:email IRI
}
:Employee {
  &:name ;
  :employeeId .
}
```

```
:Employee {
  ( schema:name .
  | schema:givenName . ;
    schema:familyName .) ;
  :employeeId .
}
```

Inverse triple constraints

^ reverses the order of the triple constraint

```
:User {
 schema:name      xsd:string ;
 schema:worksFor @:Company
}

:Company {
 a         [schema:Company] ;
 ^schema:worksFor @:User+
}
```

```
:alice schema:name "Alice";
       schema:worksFor :OurCompany .

:bob schema:name "Bob" ;
     schema:worksFor :OurCompany .

:OurCompany a schema:Company .
```

Try it (RDFShape): https://goo.gl/9FbHi3

Allowing other triples

Triple constraints limit all triples with a given predicate to match one of the constraints

This is called *closing a property*

Example:

```
<Company> {
 a [ schema:Organization ] ;
 a [ org:Organization ]
}
```

```
:OurCompany a org:Organization,
              schema:Organization .

:OurUniversity a org:Organization,        ☹
                 schema:Organization,
                 schema:CollegeOrUniversity .
```

Sometimes we would like to permit other triples (open the property)

Allowing other triples

EXTRA `<listOfProperties>` declares that a list of properties can contain extra values

```
<Company> EXTRA a {
 a [ schema:Organization ] ;
 a [ org:Organization ]
}
```

```
:OurCompany a org:Organization,
                schema:Organization .

:OurUniversity a org:Organization,
                  schema:Organization,
                  schema:CollegeOrUniversity .
```

Try it: https://goo.gl/MxZVts

Closed Shapes

CLOSED can be used to limit the appearance of any predicate not mentioned in the shape expression

```
<User> {
 schema:name IRI;
 schema:knows @<User>*
}
```

By default open, so all match <User>

```
:alice schema:name "Alice" ;
       schema:knows :bob .

:bob schema:name "Bob" ;
     schema:knows :alice .

:dave schema:name "Dave" ;
      schema:knows :emily ;
      :link2virus <virus> .

:emily schema:name "Emily" ;
       schema:knows :dave .
```

```
<User> CLOSED {
 schema:name IRI;
 schema:knows @<User>*
}
```

With closed, only `:alice` and `:bob` match <User>

Node constraints

Constraints on the focus node

```
<User> IRI {
  schema:name xsd:string ;
  schema:worksFor IRI
}
```

```
:alice schema:name "Alice";
  :worksFor :OurCompany .

_:1 schema:name "Unknown";
  :worksFor :OurCompany .
```

☹

Composing Shape Expressions

It is possible to use AND , OR and NOT to compose shapes

```
:User {
 schema:name      xsd:string ;
 schema:worksFor IRI AND @:Company ?;
 schema:follows   IRI OR BNode *
}

:Company {
 schema:founder  IRI ?;
 schema:employee IRI {1,100}
}
```

```
:alice      schema:name      "Alice";
            schema:follows   :bob;
            schema:worksFor :OurCompany .

:bob        schema:name      "Robert" ;
            schema:worksFor [
             schema:Founder "Frank" ;
             schema:employee :carol ;
            ] .

:carol      schema:name      "Carol" ;
            schema:follows   [
             schema:name "Emily" ;
            ] .

:OurCompany schema:founder  :dave ;
            schema:employee :alice, :bob .
```

☹

Try it: https://goo.gl/auLBiu

Implicit AND

AND can be omitted between a node constraint and a shape

```
:User {
  schema:name xsd:string ;
  schema:worksFor IRI AND @:Company
}
```

⇔

```
:User {
  schema:name xsd:string ;
  schema:worksFor IRI @:Company
}
```

Conjunction of Shape Expressions

AND can be used to define conjunction on Shape Expressions

```
<User> { schema:name xsd:string ;
         schema:worksFor IRI
       }
       AND {
         schema:worksFor @<Company>
       }
```

Conjunctions are the default operator in SHACL

Using AND to extend shapes

AND can be used as a basic form of inheritance

```
:Person {
 a                    [ schema:Person ] ;
 schema:name          xsd:string  ;
}

:User @:Person AND {
 schema:name          MaxLength 20 ;
 schema:email         IRI
}

:Student @:User AND {
 :course              IRI *;
}
```

```
:alice a             schema:Person ;
       schema:name   "Alice" .

:bob schema:name     "Robert";
     schema:email    <bob@example.org> .

:carol a             schema:Person;
       schema:name   "Carol" ;
       schema:email  <carol@example.org> .

:dave  a     schema:Person;
       schema:name   "Carol" ;
       schema:email  <carol@example.org>;
       :course       :algebra .
```

Disjunction of Shape Expressions

OR can be used to define disjunction of Shape Expressions

```
:User { schema:name xsd:string }
   OR { schema:givenName xsd:string ;
        schema:familyName xsd:string
      }
```

Inclusive-or

```
:User { schema:name xsd:string
      | schema:givenName xsd:string ;
        schema:familyName xsd:string
      }
```

Exclusive-or

Disjunction of datatypes

```
:Product {
 rdfs:label          xsd:string OR rdf:langString;
 schema:releaseDate xsd:date OR xsd:gYear OR
                    [ "unknown-past" "unknown-future" ]
}
```

```
:p1 a :Product ;                              #Passes as a :Product
    rdfs:label "Laptop";
    schema:releaseDate "1990"^^xsd:gYear .

:p2 a :Product ;                              #Passes as a :Product
    rdfs:label "Car"@en ;
    schema:releaseDate "unknown-future" .

:p3 a :Product ;                              #Fails as a :Product
    rdfs:label :House ;
    schema:releaseDate "2020"^^xsd:integer .
```

Exercise

Emulate recursive property paths in ShEx

- A node conforms to :Person if it has rdf:type schema:Person or if it has a type that is a rdfs:subClassOf some type that has rdf:type schema:Person

```
:alice      a schema:Person .                    #Passes as :Person

:bob        a :Teacher .                         #Passes as :Person

:carol      a :Assistant .                       #Passes as :Person

:Teacher    rdfs:subClassOf schema:Person .
:Assistant rdfs:subClassOf :Teacher .
```

Negation

NOT s creates a new shape expression from a shape s.

Nodes conform to NOT s when they do not conform to s.

```
:NoName Not {
  schema:name .
}
```

```
:alice schema:givenName  "Alice" ;
       schema:familyName "Cooper" .

:bob   schema:name       "Robert" .         ☹

:carol schema:givenName  "Carol" ;          ☹
       schema:name       "Carol" .
```

Try it: https://goo.gl/GMvXy7

IF-THEN pattern

All products must have a schema:productID and if a product has type schema:Vehicle, then it must have the properties schema:vehicleEngine and schema:fuelType.

```
:kitt schema:productID "C21";     # Passes as :Product
      a schema:Vehicle;
      schema:vehicleEngine :x42 ;
      schema:fuelType :electric .

:bad  schema:productID "C22";     # Fails as :Product
      a schema:Vehicle;
      schema:fuelType :electric .

:c23  schema:productID "C23" ;    # Passes as :Product
      a schema:Computer .
```

IF-THEN-ELSE pattern

If a product has type schema:Vehicle, then it must have the properties schema:vehicleEngine and schema:fuelType, otherwise, it must have the property schema:category with a xsd:s

```
:kitt a schema:Vehicle;                # Passes as :Product
      schema:vehicleEngine :x42 ;
      schema:fuelType :electric .

:c23  a schema:Computer ;              # Passes as :Product
      schema:category "Laptop" .

:bad1 a schema:Vehicle;                # Fails as :Product
      schema:fuelType :electric .

:bad2 a schema:Computer .              # Fails as :Product
```

Cyclic dependencies with negation

One problem of combining NOT and recursion is the possibility of declaring ill-defined shapes

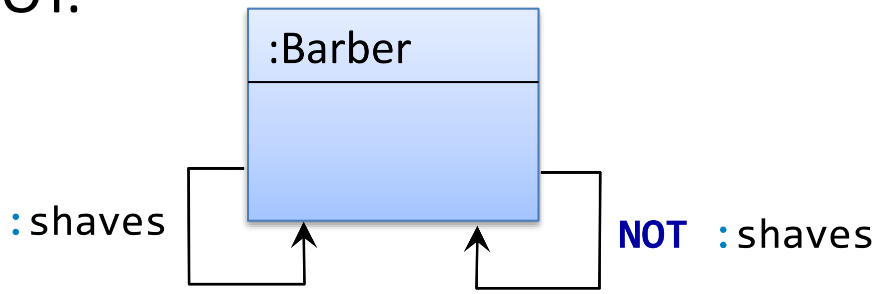
```
:Barber {                       # Violates the negation requirement
 :shaves      @:Person
} AND NOT {
 :shaves      @:Barber
}

:Person {
 schema:name xsd:string
}
```

```
:albert :shaves :dave .            # Passes as a :Barber

:bob schema:name "Robert" ;        # Passes as a :Person
     :shaves :bob .                # Passes :Barber?

:dave schema:name "Dave" .         # Passes as a :Person
```

Restriction on cyclic dependencies and negation

Requirement to avoid ill formed data models:

Whenever a shape refers to itself either directly or indirectly, the chain of references cannot traverse an occurrence of the negation operation NOT.



:Barber shape is rejected

Semantic Actions

Arbitrary code attached to shapes

- Can be used to perform operations with side effects
- Independent of any language/technology
  - Several extension languages: GenX, GenJ (http://shex.io/extensions/)

```
<Person> {
 schema:name xsd:string,
 schema:birthDate xsd:dateTime
 %js:{ report = _.o; return true; %},
 schema:deathDate xsd:dateTime
 %js:{ return _[1].triple.o.lex > report.lex; %}
 %sparql:{
  ?s schema:birthDate ?bd . FILTER (?o > ?bd) %}
}
```

```
:alice schema:name "Alice" ;
  schema:birthDate "1980-01-23"^^xsd:date ;
  schema:deathDate "2013-01-23"^^xsd:date .

:bob schema:name "Robert" ;
  schema:birthDate "2013-08-12"^^xsd:date ;
  schema:deathDate "1990-01-23"^^xsd:date .
```

Importing schemas

The import statement allows to import schemas

http://example.org/Person.shex

```
:Person {
   $:name ( schema:name .
          | schema:givenName . ; schema:familyName .
          ) ;
   schema:email .
}
```

```
import <http://example.org/Person.shex>

:Employee {
    &:name ;
    schema:worksFor <CompanyShape>
}

:Company {
    schema:employee @:Employee ;
    schema:founder  @:Person ;
}
```

```
:alice schema:name     "Alice";
       schema:worksFor :OurCompany .

:OurCompany schema:employee :alice ;
            schema:founder  :bob .

:bob schema:name "Robert" ;
     schema:email <mailto:bob@example.com> .
```

Annotations

Annotations are lists (predicate, object) that can be associated to an element

Specific annotations can be defined for special purposes, e.g. forms, UI, etc.

```
:Person {
 schema:name       xsd:string
  // rdfs:label     "Name"
  // rdfs:comment  "Name of person" ;

 schema:birthDate xsd:date
   // rdfs:label     "birthDate"
   // rdfs:comment  "Birth of date" ;
}
```

Other features

Current ShEx version: 2.1

Some features postponed for next version

- Inheritance (extends/abstract)
- UNIQUE

Future work & contributions

- More info http://shex.io
  - ShEx currently under active development
  - Curent work
    - Improve error messages
    - Inheritance of shape expressions
- If you are interested, you can help
  - List of issues: https://github.com/shexSpec/shex/issues

Shapes tools

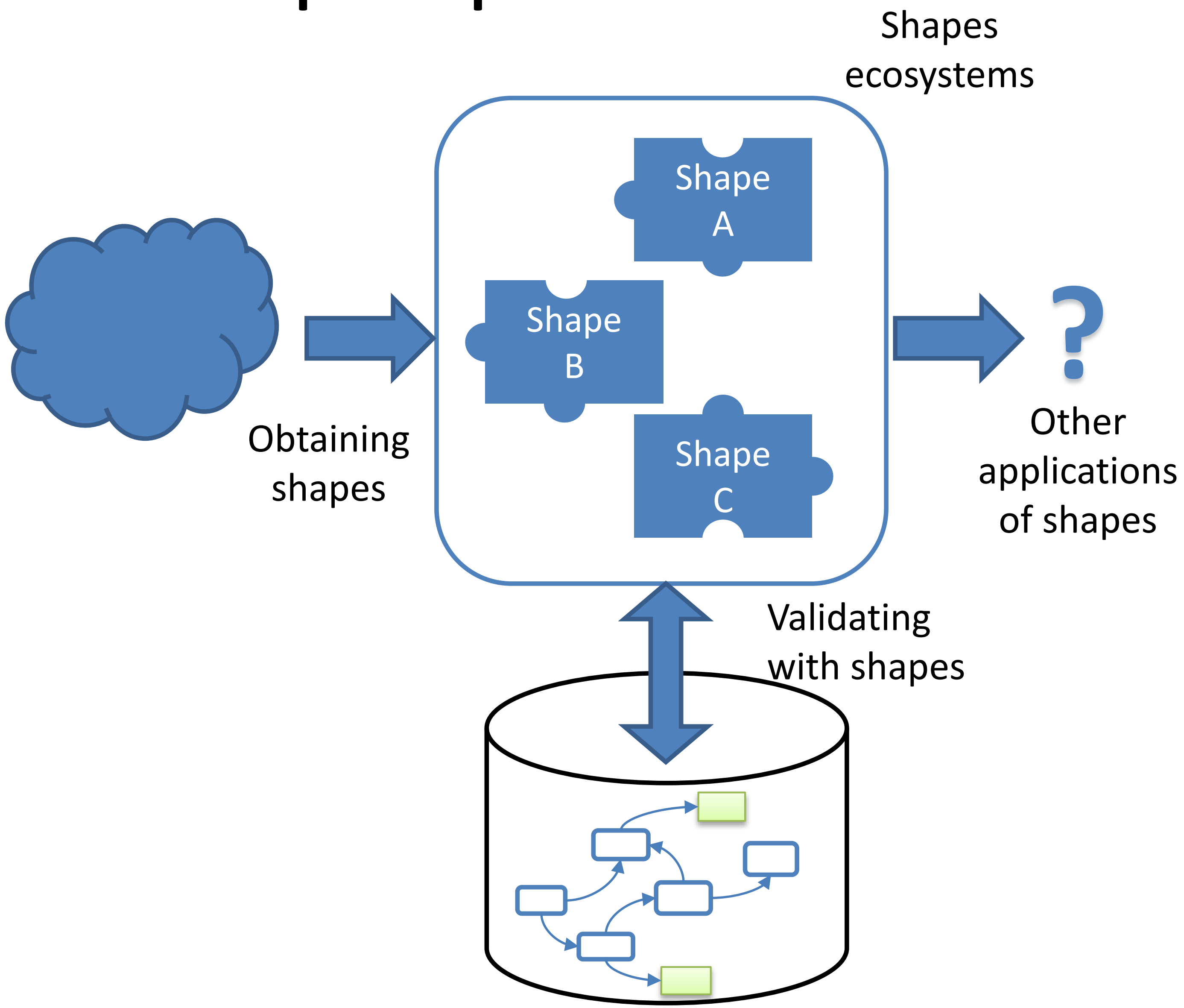
Tools: challenges and perspectives

Validating with shapes

Obtaining shapes

Other applications of shapes

Shapes ecosystems



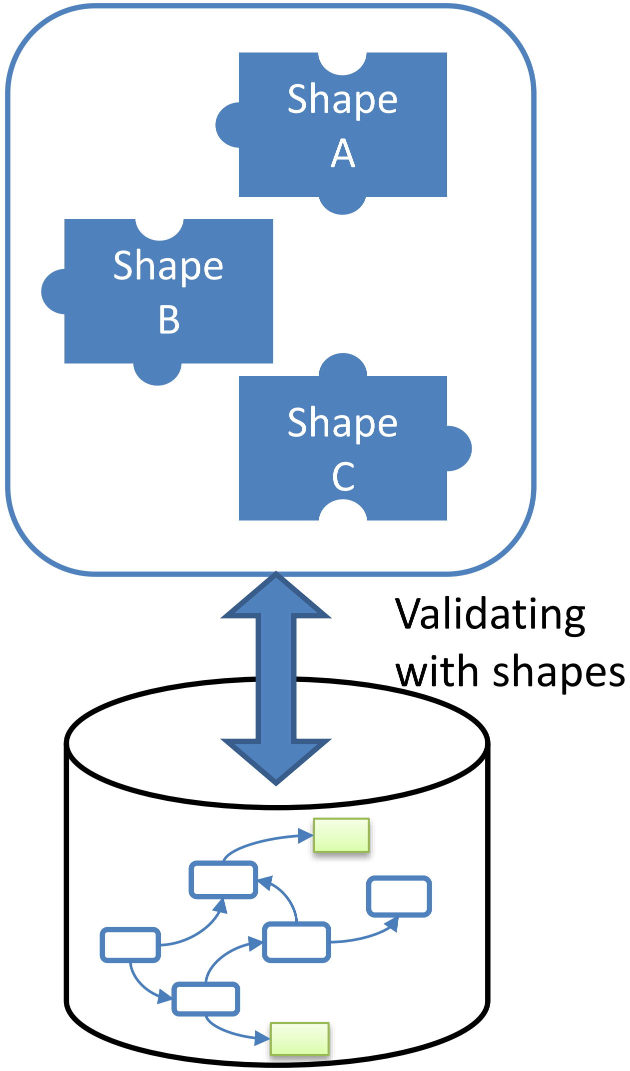
Validating with shapes

Libraries and command line validators

Online demos

Integrated in ontology editors

Continuous integration with Shapes



Libraries and command line validators

Examples at WESO

SHaclEx

RDF validation
Generic schemas: ShEx/SHACL
Converter ShEx ↔ SHACL

ShEx-s

Scala implementation of ShEx
Supports ShEx 2.1 (testsuite)

SHACL-s

Scala implementation of SHACL
Supports SHACL core (testsuite)

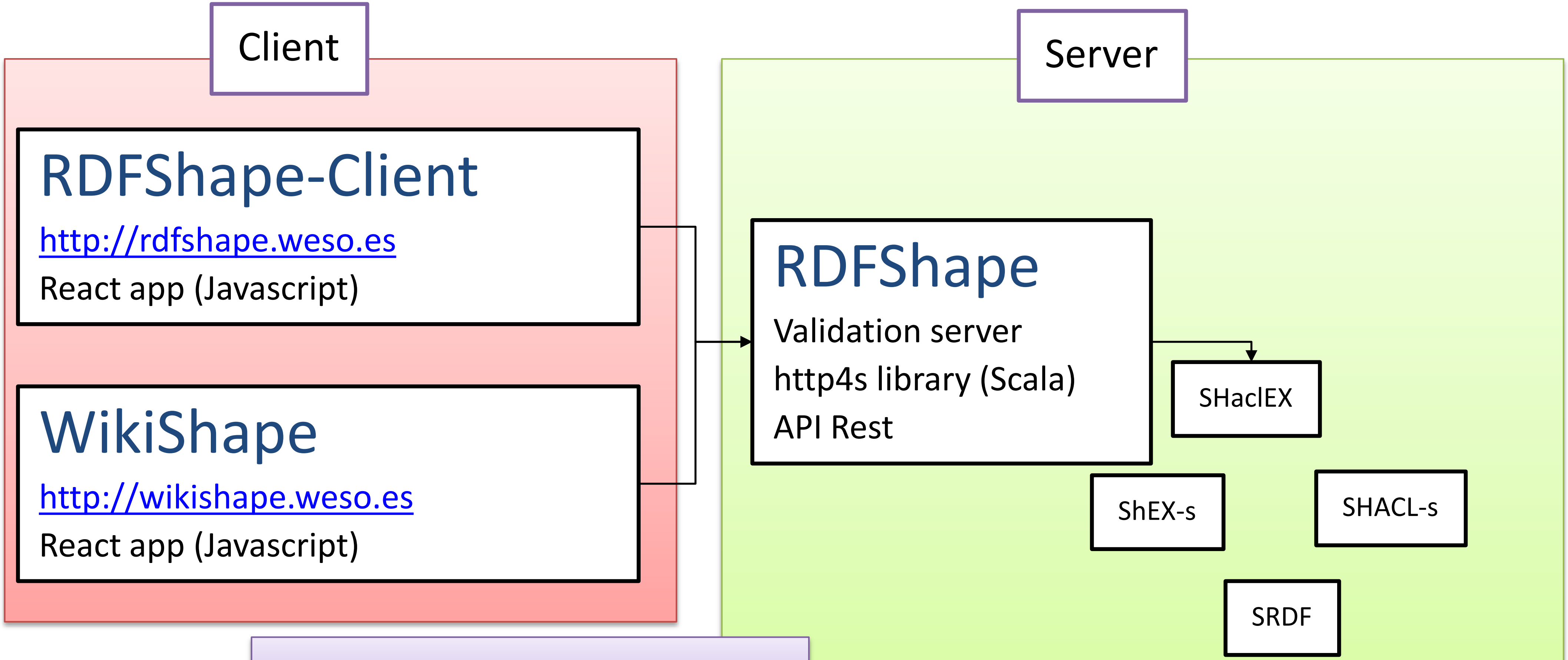
SRDF

Simple RDF - Generic RDF interface
Implementation for RDF4j and Apache Jena

All libraries are available at: https://github.com/weso/

Online demos

Web Demos and playgrounds



Example RDFShape: https://tinyurl.com/shqrban

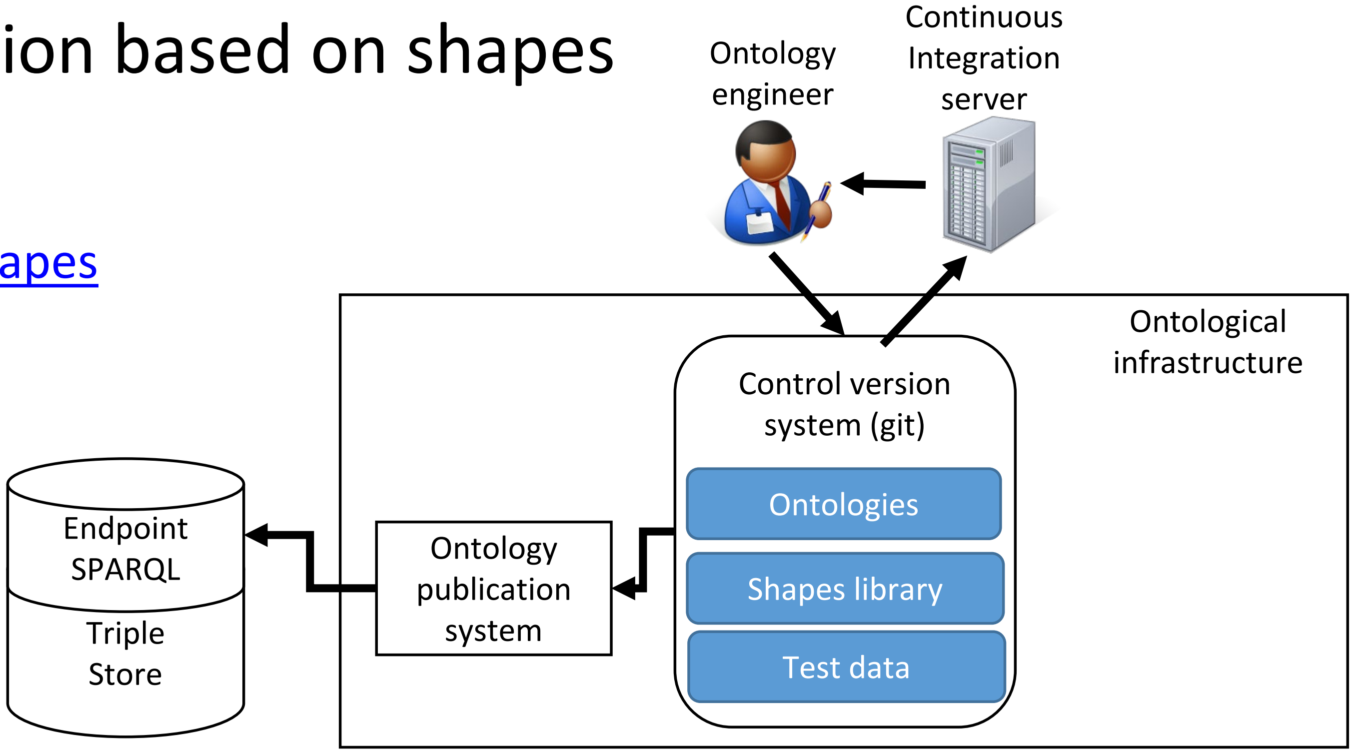
Continuous integration with Shapes

Coexistence between ontologies/shapes

- Shapes can validate the behaviour of inference systems
- Shapes pre- and post- inference
- TDD and continuous integration based on shapes

Gene Ontology Shapes:

- https://github.com/geneontology/go-shapes



Continuous integration with Shapes

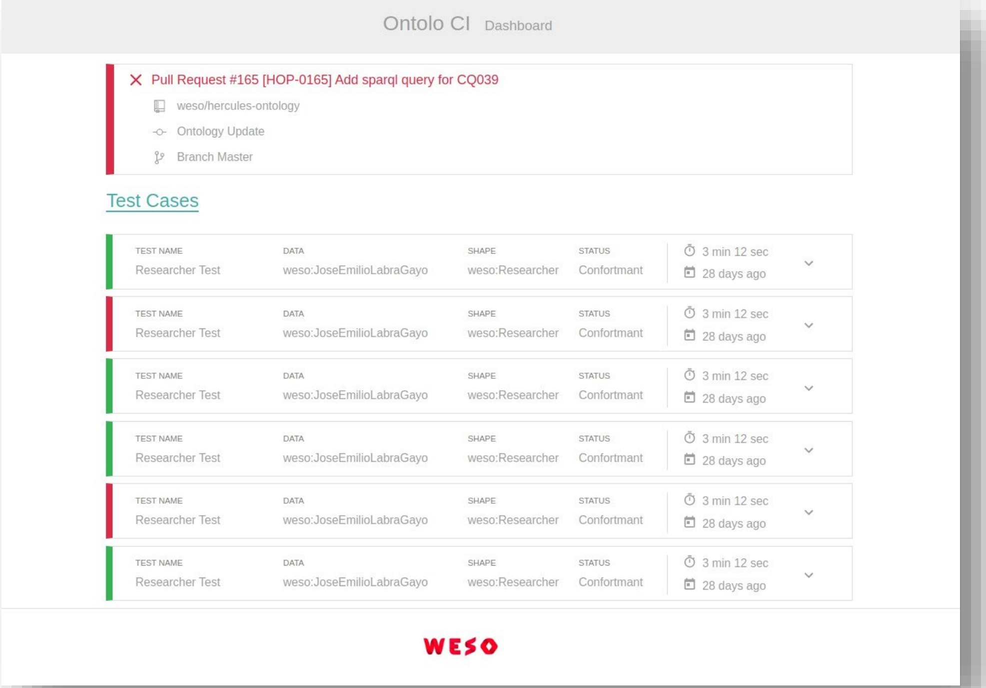
Ontolo-ci: https://www.weso.es/ontolo-ci/

Developed as part of HERCULES-Ontology

Test-Driven-Development applied to Ontologies

Input:

- Ontologies
- Shapes
- Test data
- Input shape map (SPARQL competency question)
- Expected result shape map



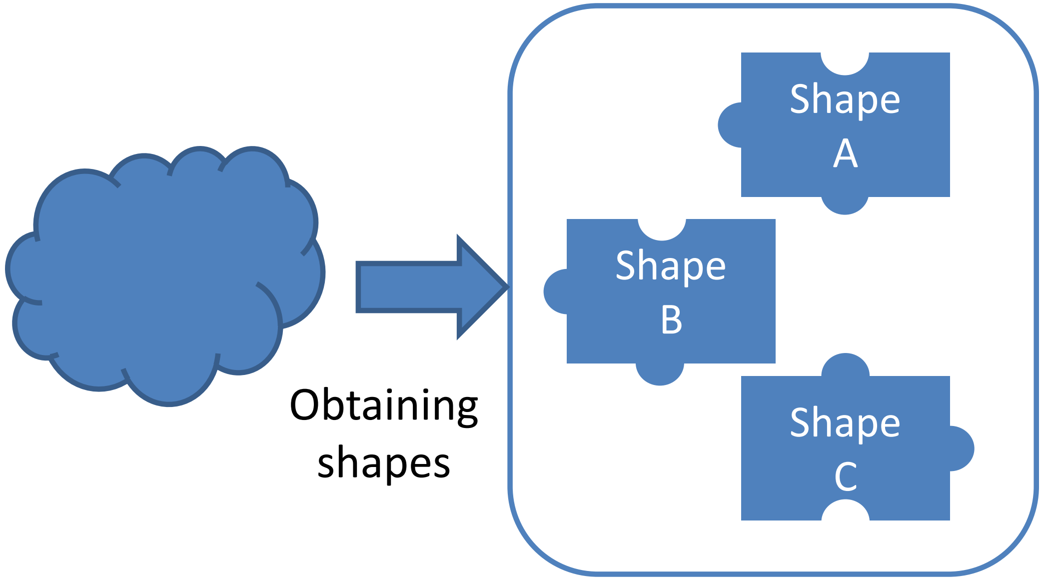
Obtaining shapes

Shapes editors

- Text-based editors
- Visual editors and visualizers

Obtaining shapes from...

- Spreadsheets
- RDF data
- Ontologies
- Other schemas (XML Schema)



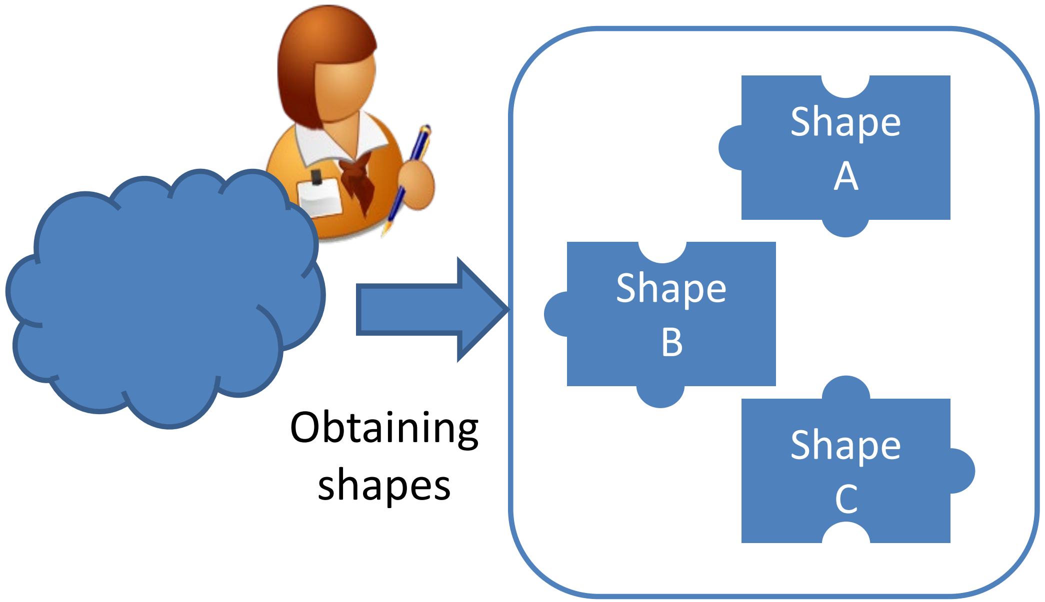
Text-based editors

YaSHE: Forked from YASGUI: http://www.weso.es/YASHE/

- Syntax highlighting
- Auto-completion

Shapes author tools

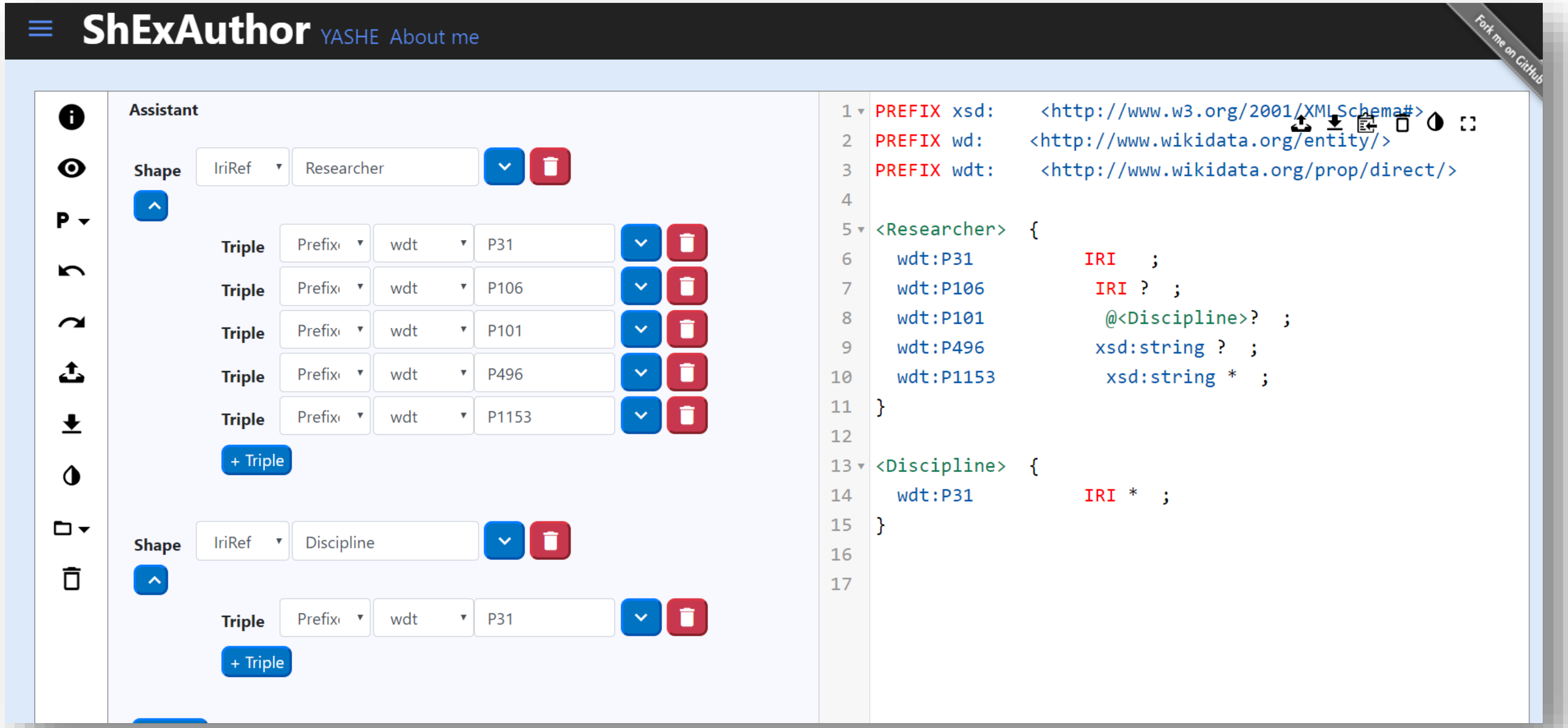
ShEx-Author



Shapes author tools: ShEx Author

ShEx-Author: Inspired by Wikidata Query Service

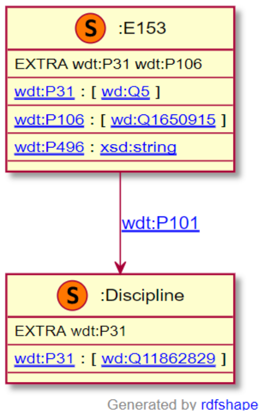
2 column: Visual one synchronized with text based

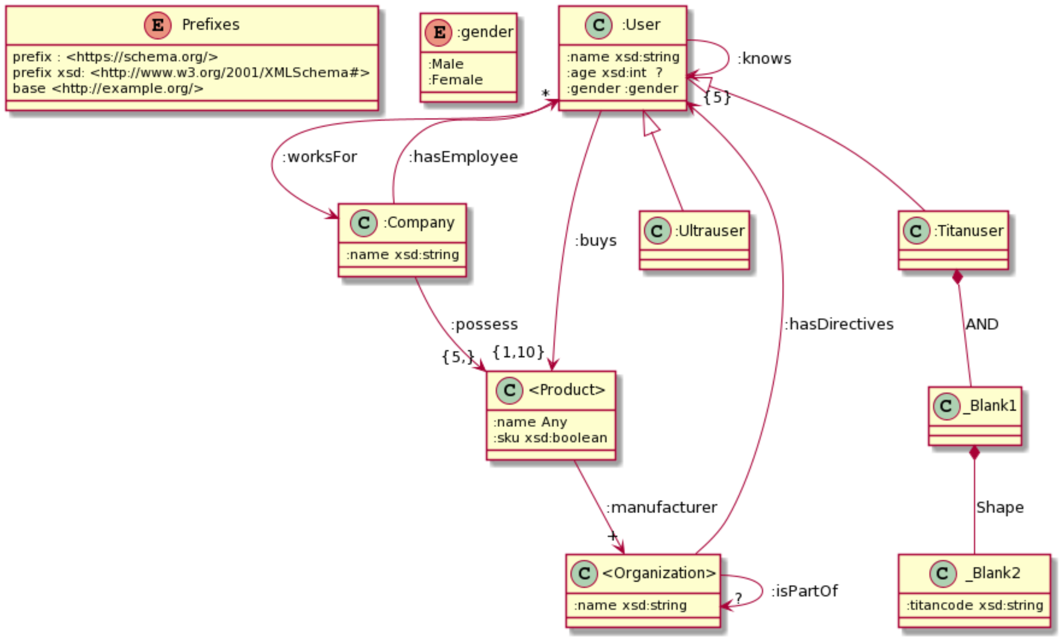


Shapes visualization

Integrated in RDFShape/Wikishape

- [UMLSHaclEX](#) UML diagrams for ShEx
- [ShUMLex:](#) Conversion to UML through XMI





Shapes from spreadsheets

ShExstatements: https://shexstatements.toolforge.org/

ShExCSV: CSV representation of Shapes

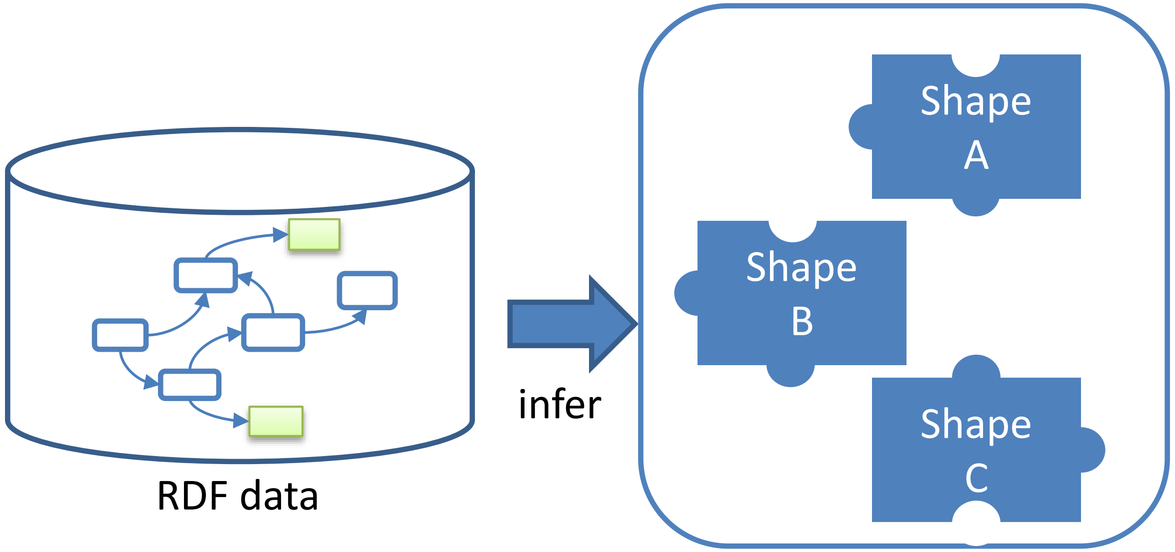
Hermes: ShExCSV processor, https://github.com/weso/hermes

Generating Shapes from RDF data

Useful use case in practice

Some prototypes

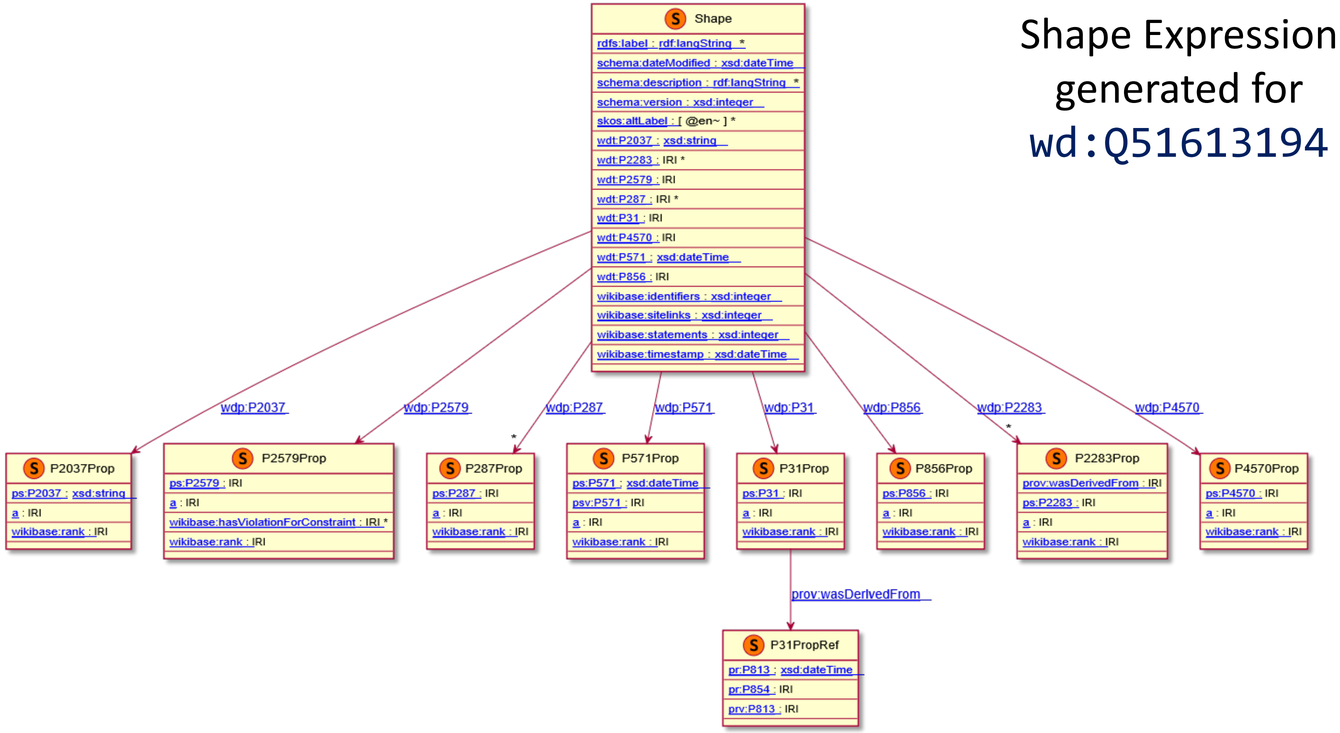
- sheXer: http://shexer.weso.es/
- RDFShape: http://rdfshape.weso.es
- ShapeDesigner: https://gitlab.inria.fr/jdusart/shexjapp



Try it with RDFShape:
https://tinyurl.com/y8pjcbyf

Shapes from data: RDFShape

RDFShape/Wikishape implement a basic prototype to derive Shapes from RDF data



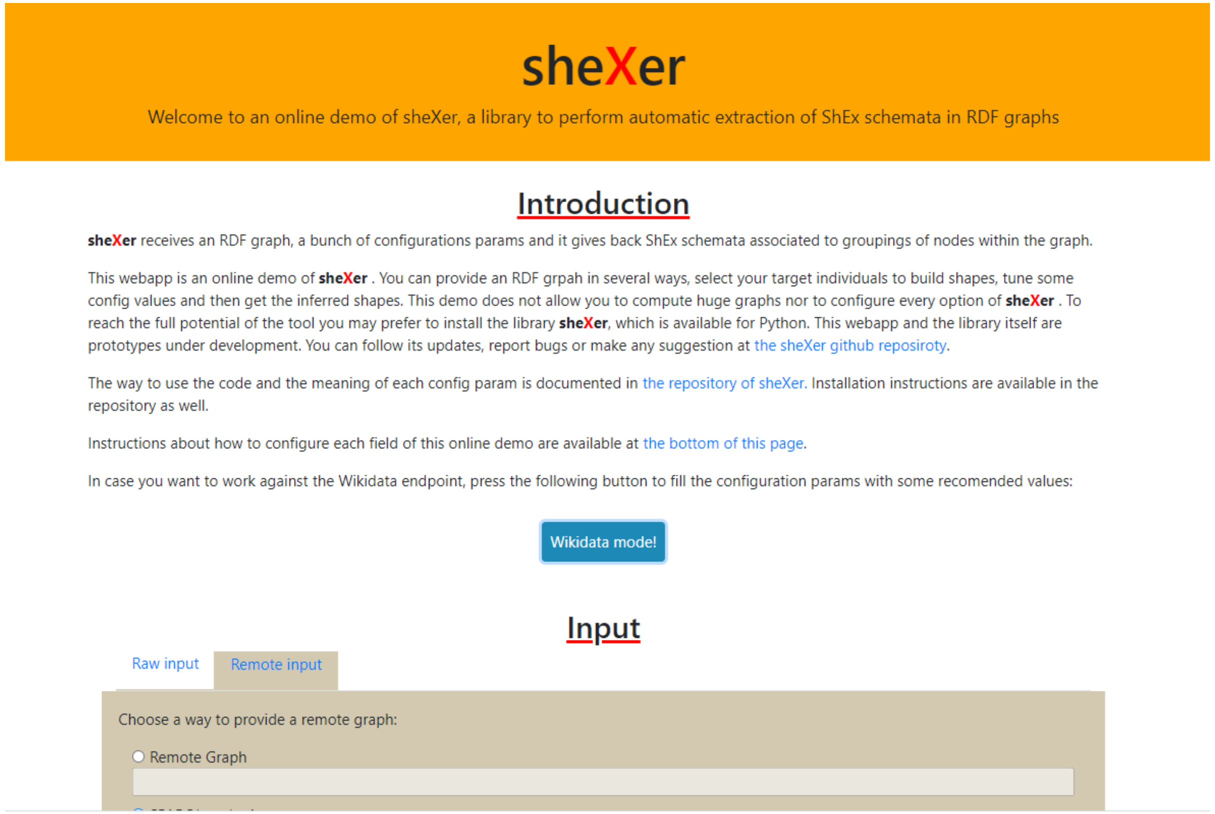
Shape Expression generated for `wd:Q51613194`

Shapes from data: sheXer

sheXer: http://shexer.weso.es/

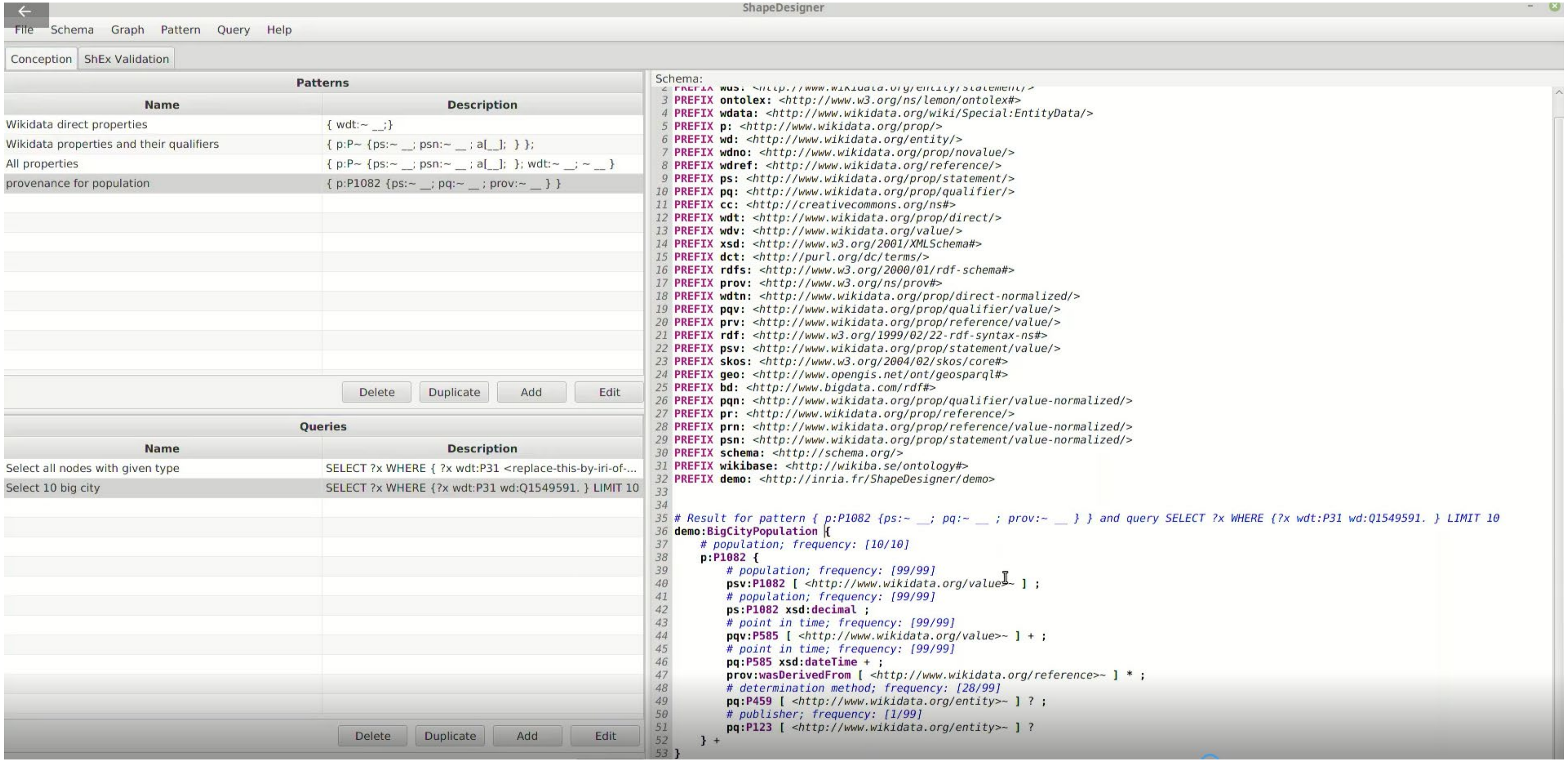
Implemented in Python

Configuration options



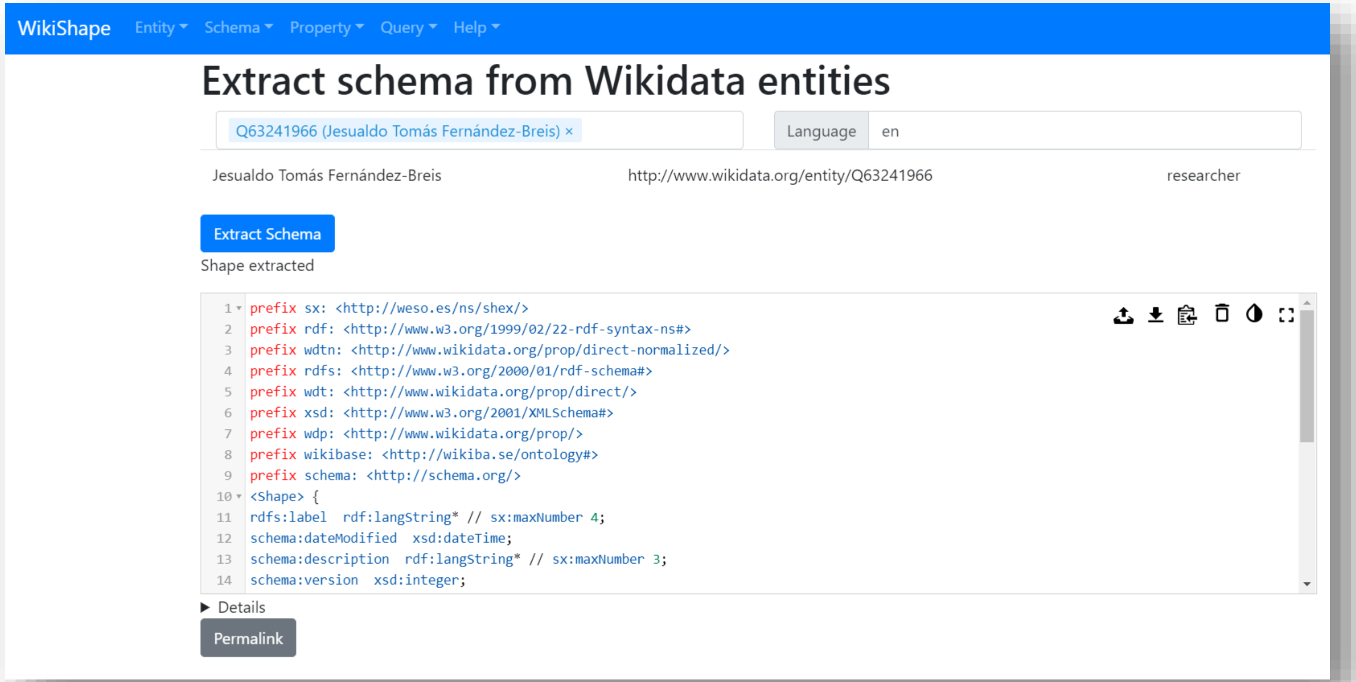
Shapes from data: ShapeDesigner

https://gitlab.inria.fr/jdusart/shexjapp



Shapes from RDF data

RDFShape allows to infer basic shapes automatically



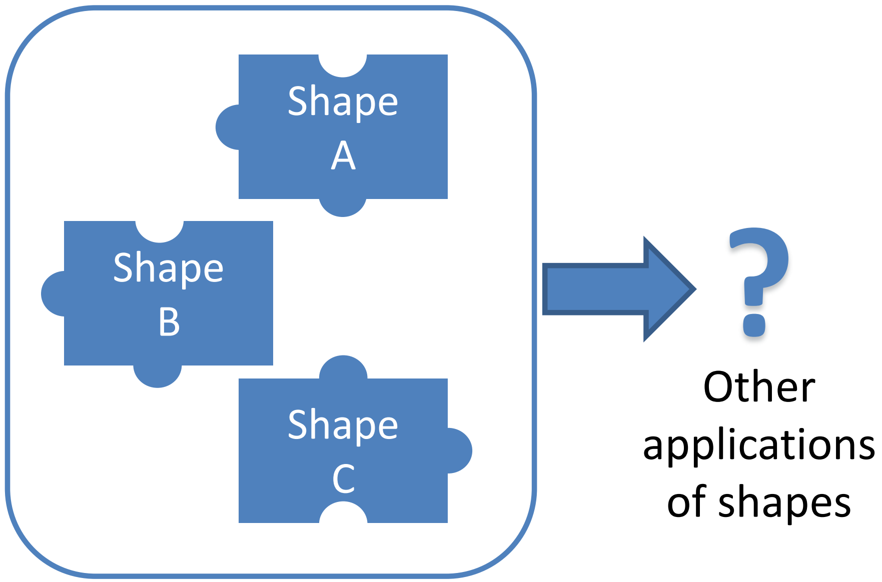
Other applications of Shapes

UIs and shapes

Generating code from Shapes

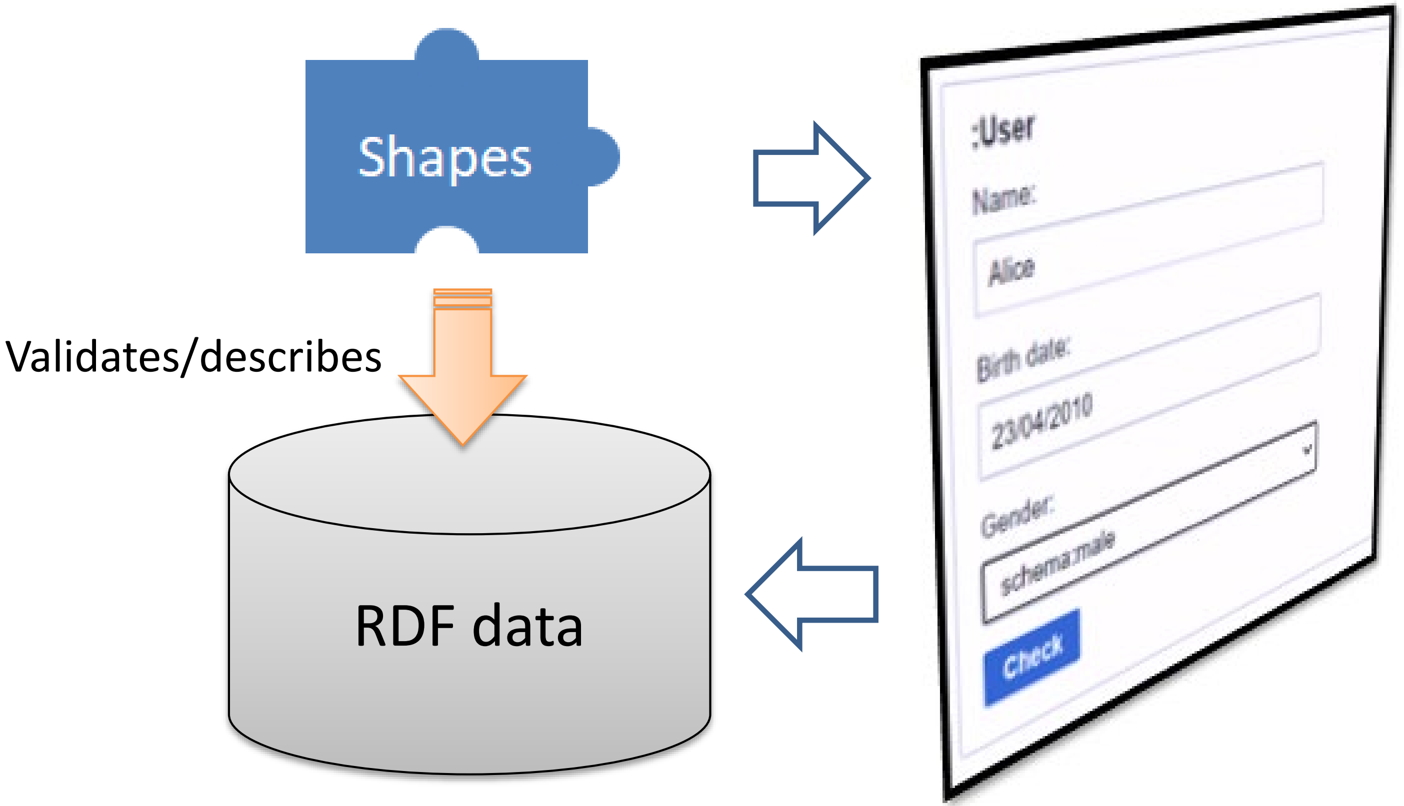
Shapes and rules

Generate subsettings



UIs and shapes

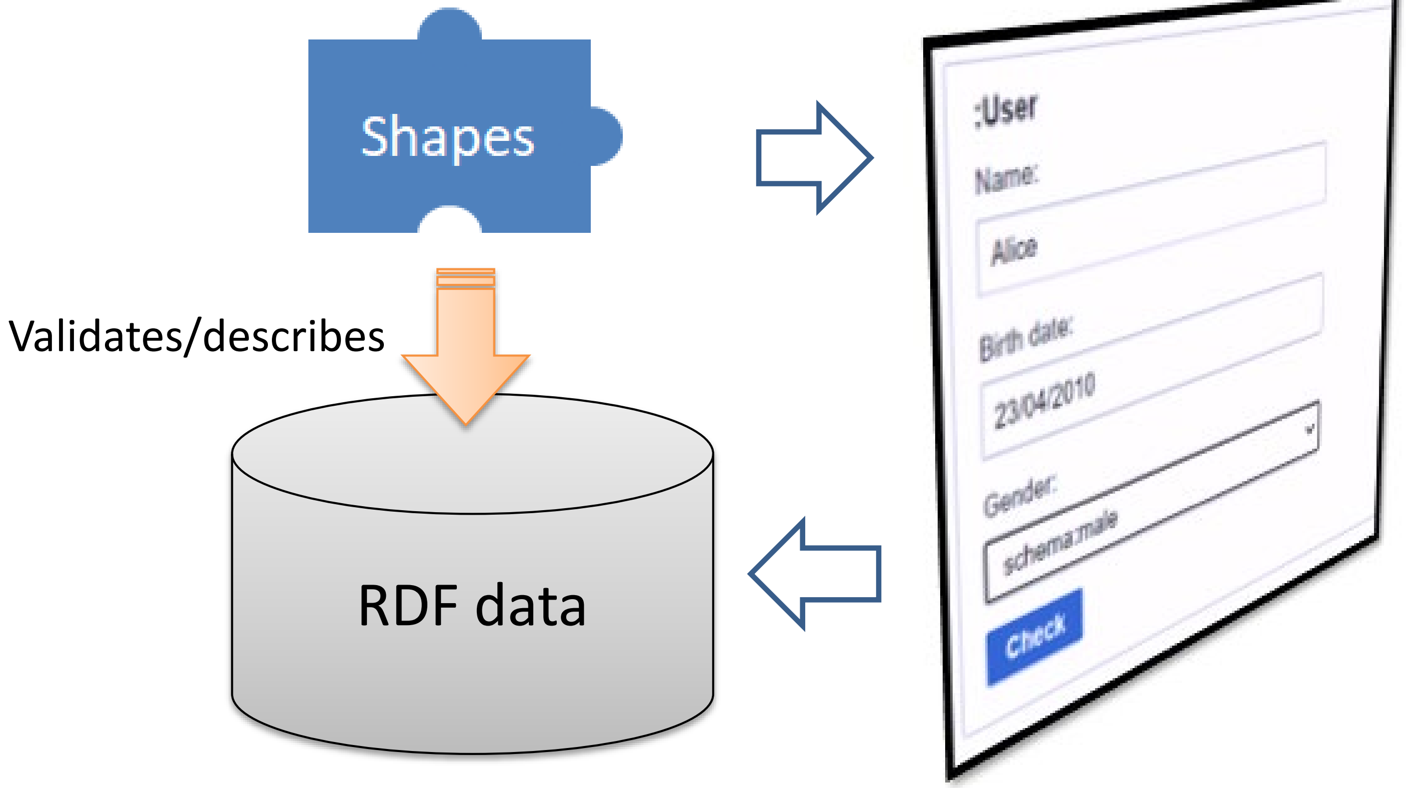
Shapes can provide hints to generate user interfaces/forms



UI and shapes: ShapeForms

ShapeForms

```
prefix schema: <http://schema.org/>
prefix : <http://example.org/>
prefix xsd: <http://www.w3.org/2001/XMLSchema#>
prefix ui: <http://www.w3.org/ns/ui#>

start = @:User

:User {
 schema:name  xsd:string       // ui:label "name" ;
 schema:birthDate xsd:dateTime // ui:label "Birth date" ;
 schema:gender [ schema:Male schema:Female ] // ui:label "Gender" ;
}
```



UIs and Shapes: ShapePath and ShapeForms

ShEx Path can be used to point to parts of a ShEx schema

https://shexspec.github.io/spec/ShExPath

ShEx generated forms demo based on UI ontology:

https://ericprud.github.io/shex-form/?manifestURL=examples/manifest.json

ShapeForms

https://github.com/weso/shapeForms

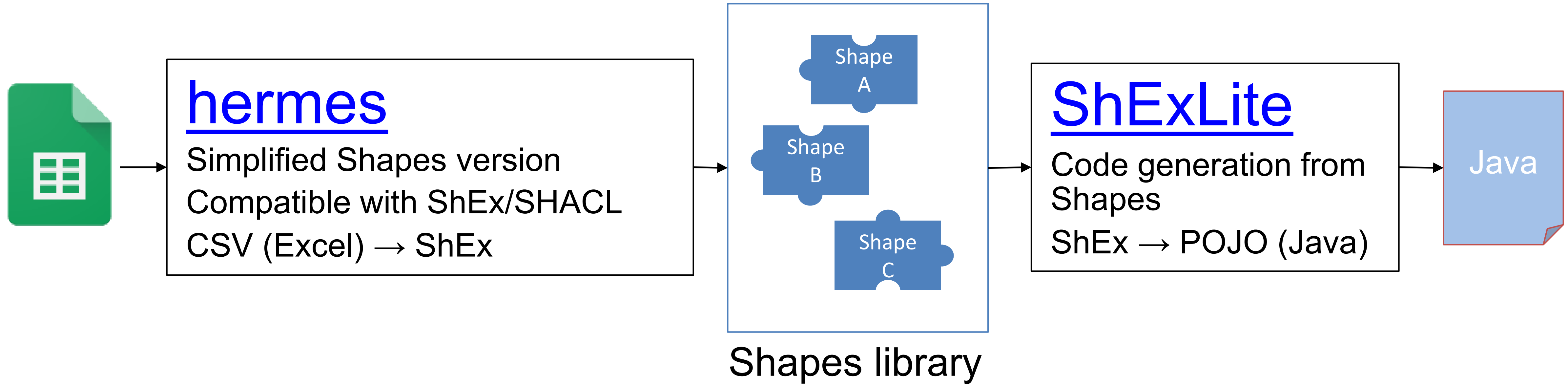
Generating code from shapes

Generate domain model from shapes

Entities (pseudo-shapes) defined with Excel (Google spreadsheets)

Shapes generation from those templates

Java code generation (POJOs) from those shapes

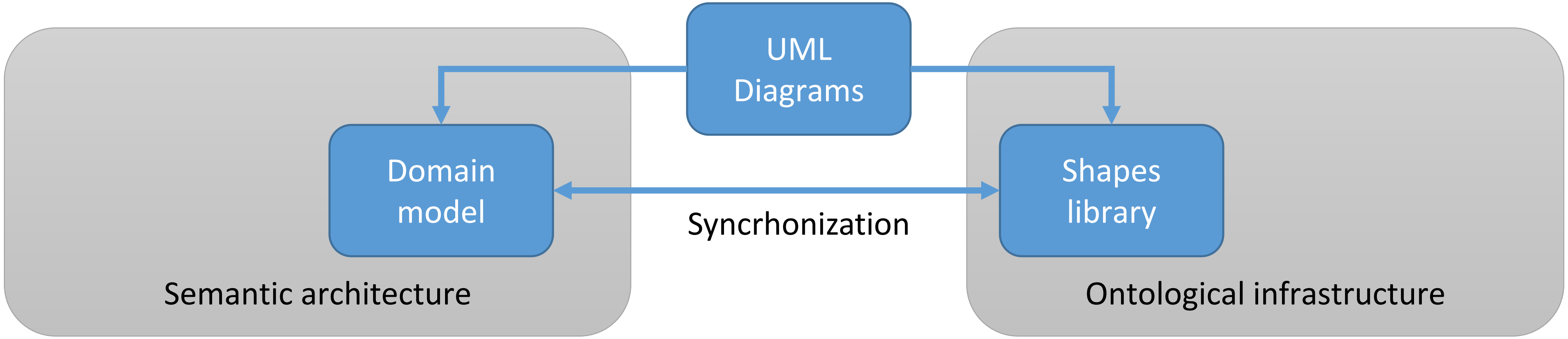


Generating code from shapes

Domain model based on Shapes

Clean architecture pattern

- Domain model as central element
- Simple classes (POJO): Plain Old Java Objects
- Shapes synchronization
- Application logic and services based on domain model

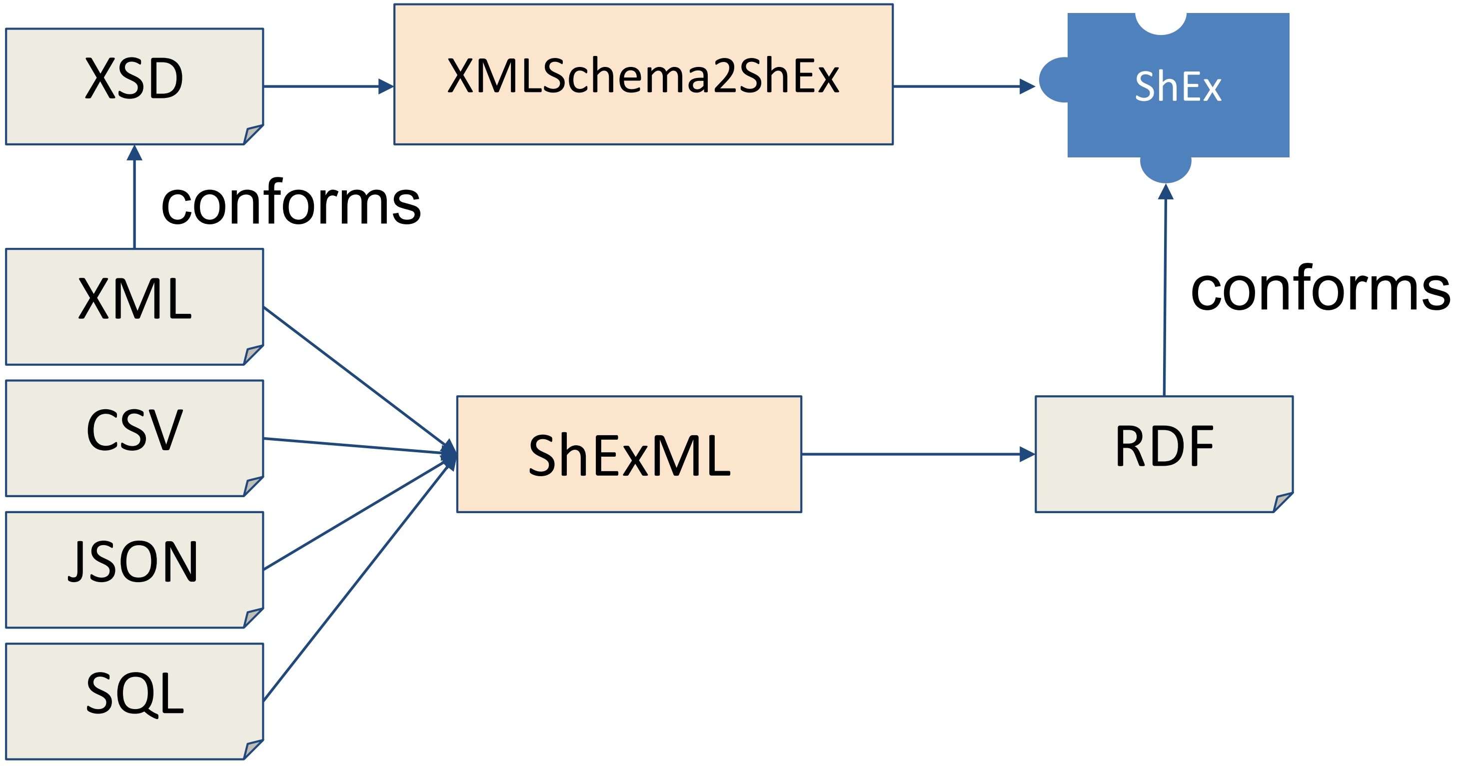


Shapes for data integration

XMLSchema2ShEx: Convert XML Schemas to shapes

ShExML: Domain specific language to convert data to RDF

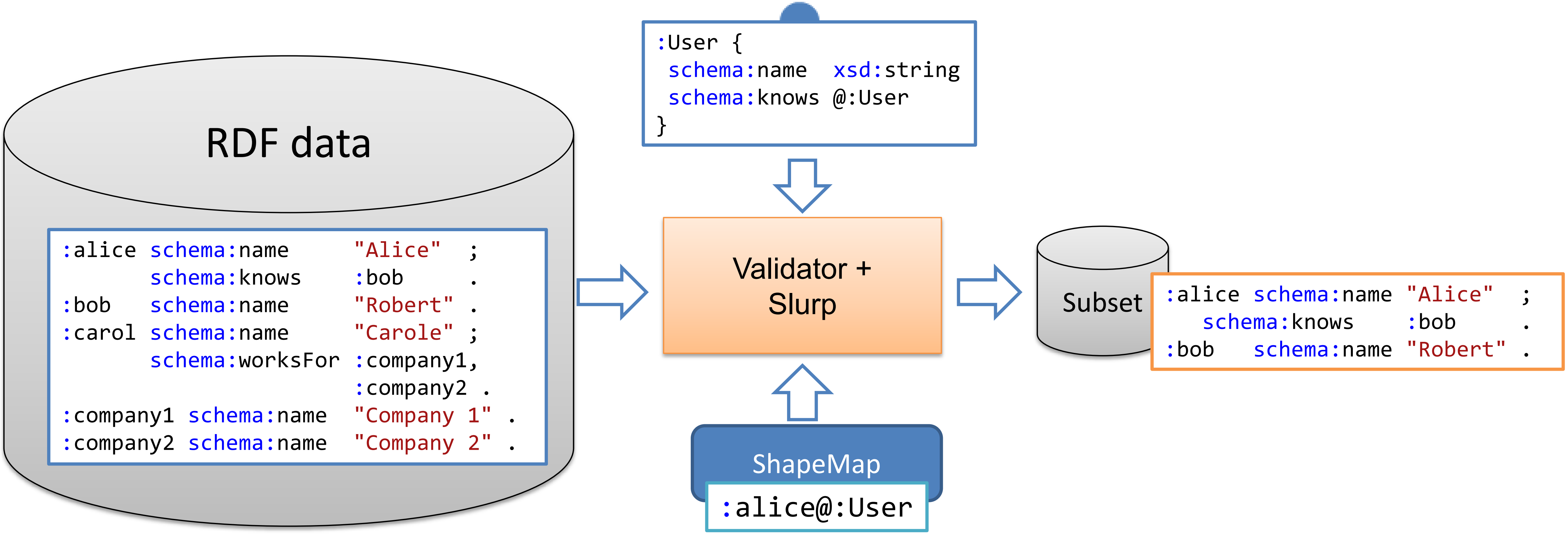
Input formats: CSV, XML, JSON, SQL



Subsetting based on Shapes

Generate subsets from ShEx

Slurp option: when validating, collect the affected nodes/triples



Shapes ecosystems

- Wikidata provides a whole ShEx ecosystem
- Entity schemas can evolve and relate between each other
  - Directory: https://www.wikidata.org/wiki/Wikidata:Database_reports/EntitySchema_directory
  - Different schemas for the same entities?
    - Some schemas stress some aspects while others stress others
  - Evolution of schemas
  - Searching entity schemas

End of presentation

Backup slides

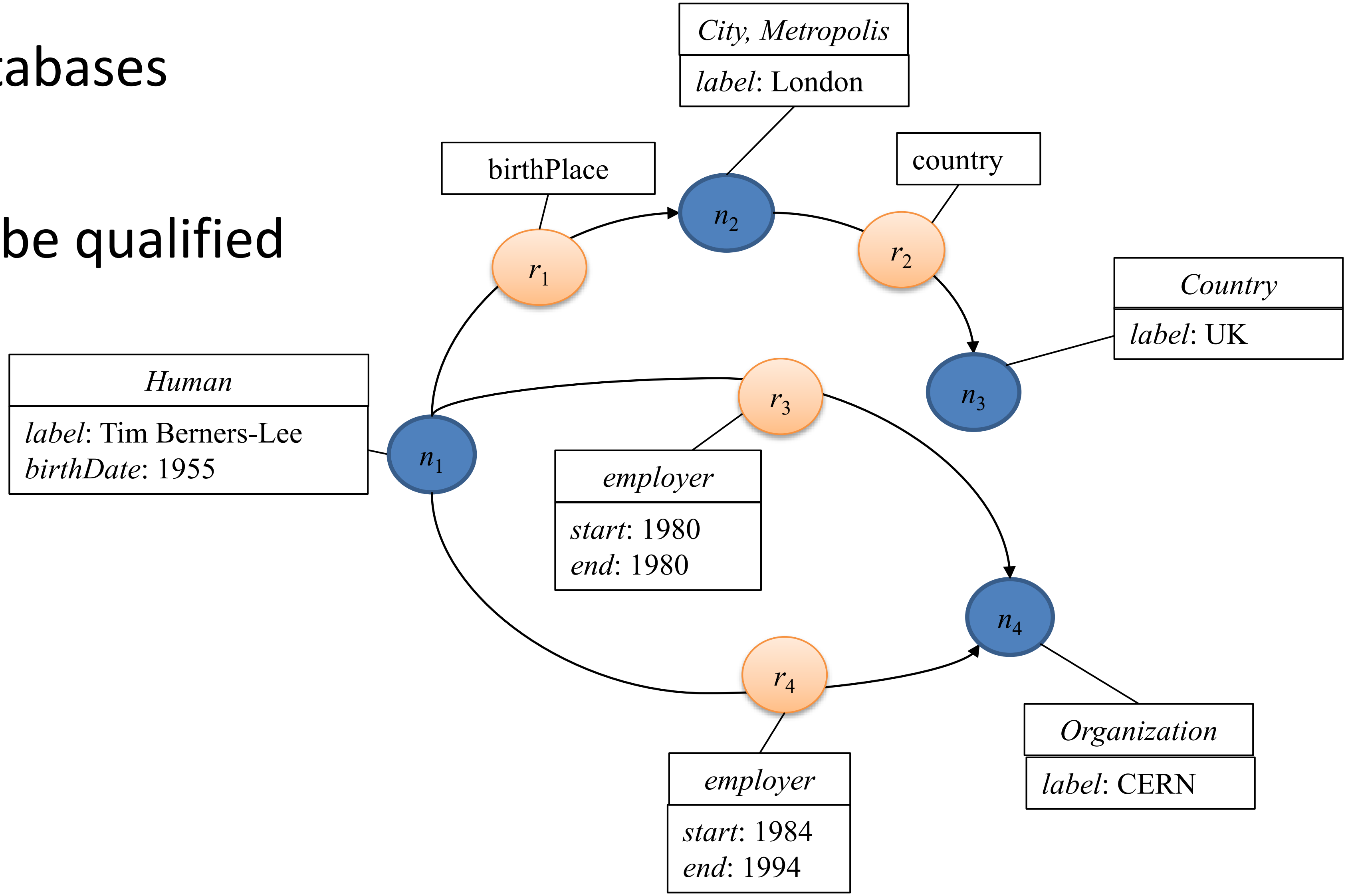
Property graphs

Popularized by graph databases

Example: Neo4J

Nodes and relations can be qualified

Nodes can have types



Semantic Web

Semantic Web = vision of the data Web

Goal: Automatically share and reuse data on the Web

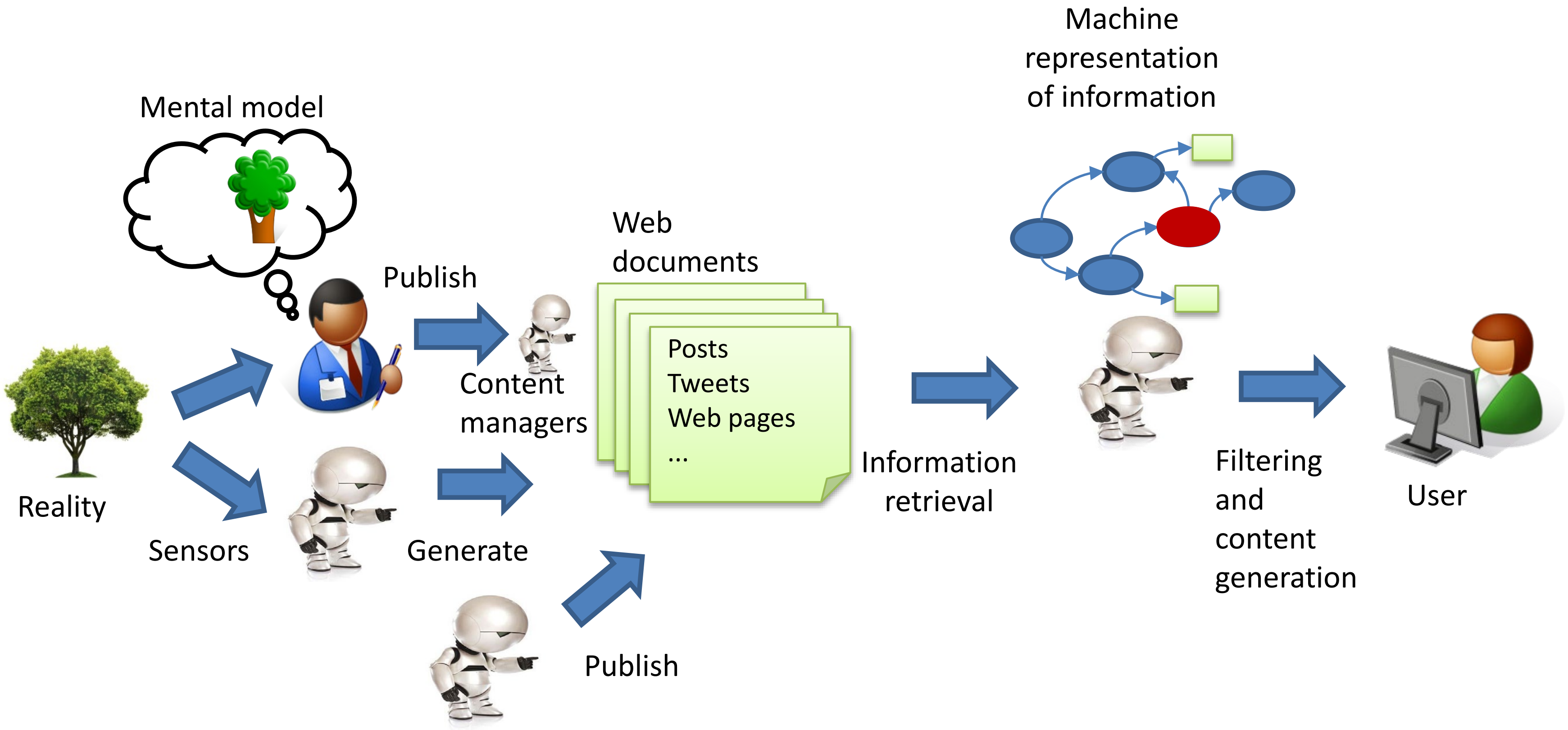
Not only documents/web pages, but also data

Long term project

- The goal is not to destroy the current web
  - Gradually adopt better practices
- Improve publication/reuse techniques
- Let machines process (understand?) more data
- Give more value to information

Tim Berners-Lee
Source: Wikipedia

Machines in the Web



Web information is constantly manipulated by machines
Goal of semantic web = facilitate that *automatic* manipulation

¿People vs Machines?

People	Machines
Creativity, imagination	Programmed for certain tasks
Unpredictable (make errors)	Predictable (without errors*)
Get tired with repetitive tasks	No problem for repetitive tasks
Understanding based on context	Dificulties to understand the context

*when they are well programmed

Representing context for machines

Example: "Oviedo has a temperature of 36"

Decomposed in:

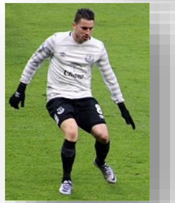
Oviedo...has a temperature of...36

Oviedo?

Oviedo, a city in Spain

Oviedo, another city in Florida, USA

Bryan Oviedo, a football player



How can we remove ambiguity?

Using URIS

https://www.oviedo.es/

https://www.cityofoviedo.net/

https://twitter.com/bryan_oviedo

Representing context for machines

Example: "Oviedo has a temperature of 36"

Decomposed in:

Oviedo...has a temperature of...36

...has a temperature of... http://example.org/hasTemperature

Is there an existing URI
for "hasTemperature" property?

http://purl.obolibrary.org/obo/PATO_0000146

Representing context for machines

Example: "Oviedo has a temperature of 36"

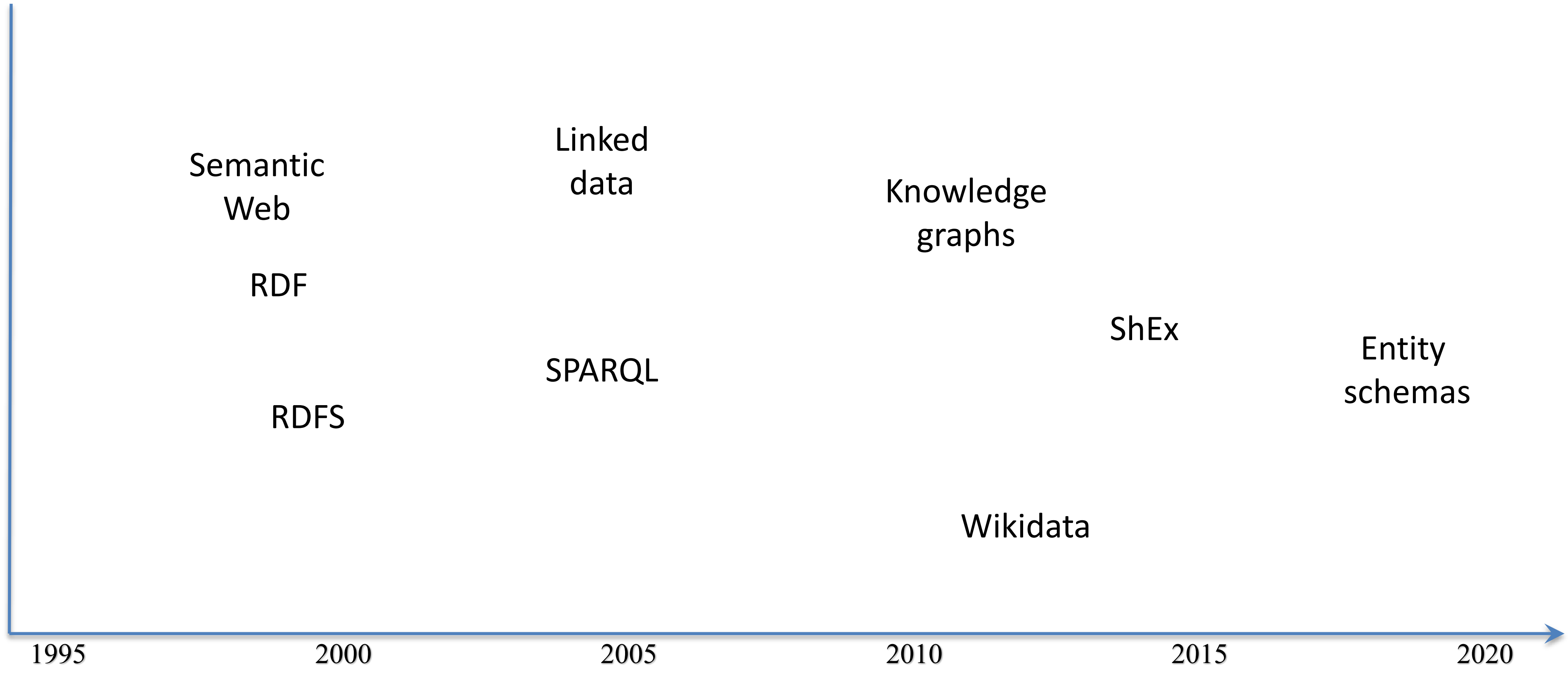
Decomposed in:

Oviedo...has a temperature of...36

https://twitter.com/bryan_oviedo $\xrightarrow{\text{http://purl.obolibrary.org/obo/PATO\_0000146}}$ 36

Is the previous representation accurate enough?
- Identify some problems about the previous definition...
- Identify several possibilities to improve that representation

Roadmap



Semantic Web
RDF
RDFS
Linked data
SPARQL
Knowledge graphs
Wikidata
ShEx
Entity schemas
1995
2000
2005
2010
2015
2020

Turtle syntax

Exercise: simplify

```
prefix :       <http://example.org/>
prefix schema: <http://schema.org/>
prefix dbr:    <http://dbpedia.org/resource>


:alice schema:knows      :bob .
:bob   schema:knows      :carol .
:carol schema:knows      :bob .
:carol schema:knows      :alice .
:bob   schema:birthPlace dbr:Spain .
:carol schema:birthPlace dbr:Spain .
```

```
prefix ex:     <http://example.org/>
prefix schema: <http://schema.org/>
prefix dbr:    <http://dbpedia.org/resource>

:alice schema:knows      :bob , :carol.
:bob   schema:knows      :carol ;
       schema:birthPlace dbr:Spain .
:carol schema:knows      :bob, :alice ;
       schema:birthPlace dbr:Spain .
```

Try it: https://tinyurl.com/y9wbdycp

From shared vocabularies to ontologies

OWL = Web Ontology Language.

OWL 1 (2004), OWL 2 (2009)

Based on description logics

Describe classes, properties, individuals and their relationships

Highly expressive and powerful inference mechanism

OWL example

Simple ontology, Terminological part (TBox)

$$Person \sqsubseteq = 2\, hasParent$$
$$Person \sqsubseteq \exists\, hasParent\, Male$$
$$Person \sqsubseteq \exists\, hasParent\, Female$$

$$Male \sqsubseteq \neg Female$$
$$Female \sqsubseteq \neg Male$$

```
:Person rdf:type owl:Class ;
 rdfs:subClassOf [
  rdf:type owl:Restriction ;
  owl:onProperty :hasParent ; owl:cardinality 2
 ], [
 rdf:type owl:Restriction ;
 owl:onProperty :hasParent ; owl:someValuesFrom :Male
 ], [
 rdf:type owl:Restriction ;
 owl:onProperty :hasParent ; owl:someValuesFrom :Female
 ] .

:Female owl:disjointWith :Male .
```

Instance data, assertional part = ABox

$$Person(alice)$$
$$hasParent(alice, bob)$$
$$hasParent(alice, carol)$$
$$Female(carol)$$

```
:alice rdf:type :Person ;
 :hasParent :bob,
            :carol .
:carol rdf:type :Female .
```

Inferred data

$$Male(bob)$$

```
:bob rdf:type :Male .
```

? The example is not complete... what is missing?

We need to declare that :bob ≠ :carol

```
[ rdf:type owl:AllDifferent ;
  owl:distinctMembers ( :bob
                        :carol
                      ) ] .
```

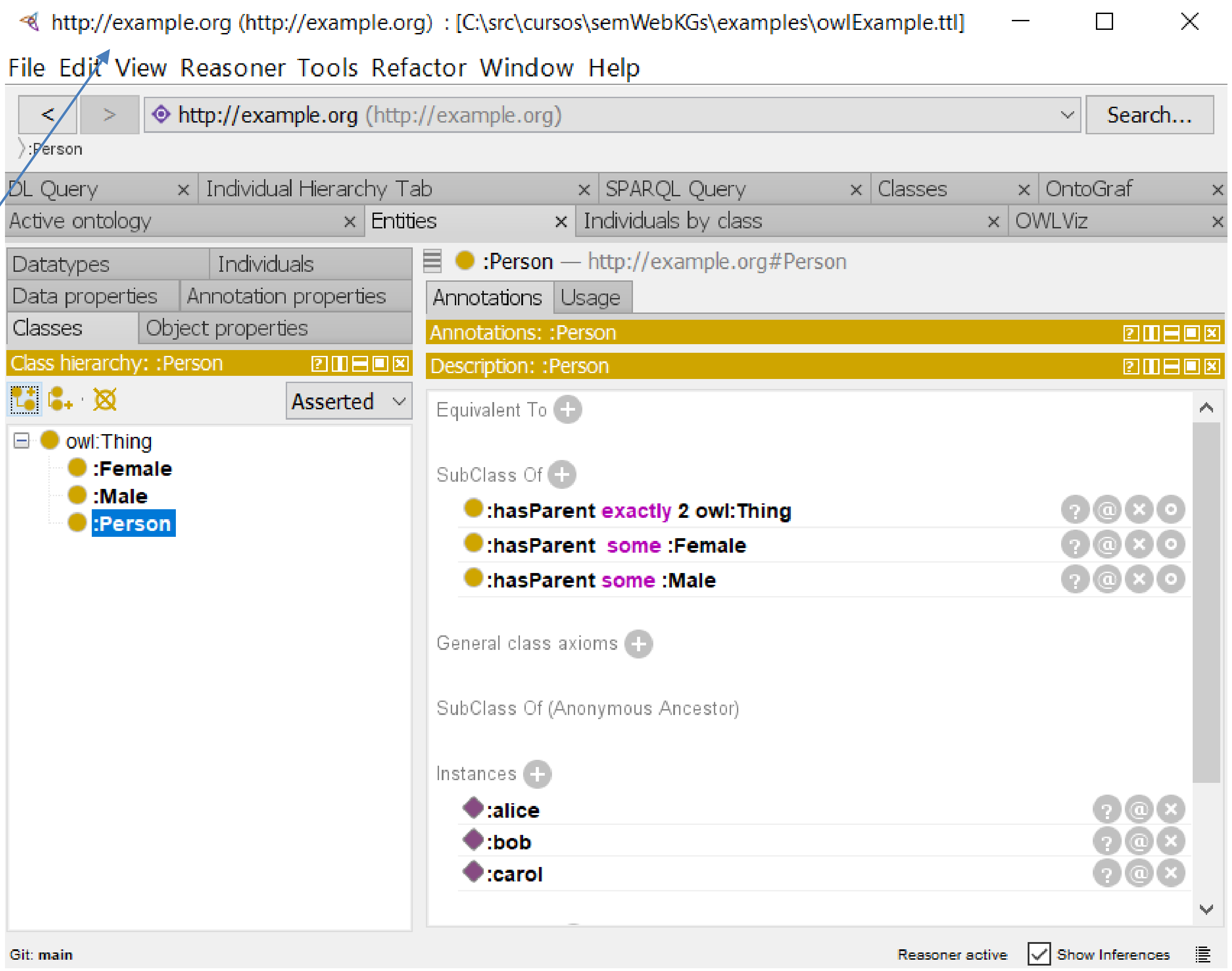
OWL

OWL = language to describe ontologies

Different kinds of ontologies:

- Upper level ontologies (SUMO, BFO, ...)
- Domain specific ontologies

Ontology editors like [Protégé editor]



Ontology concepts have a URI
They can be defined/stored in local files
How should we publish them?

Linked Data

Principles proposed by Tim Berners-Lee to publish data*:

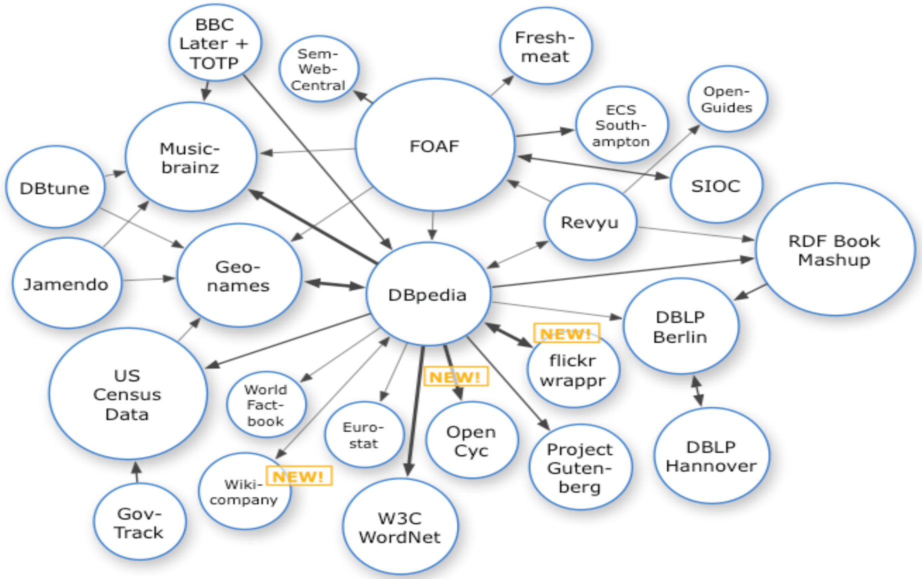
1. Use URIs to denote things
2. Use HTTP URIs so that people can look up those names
3. When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL)
4. Include links to other URIs. so that they can discover more things

* https://www.w3.org/DesignIssues/LinkedData.html

Why Linked data?

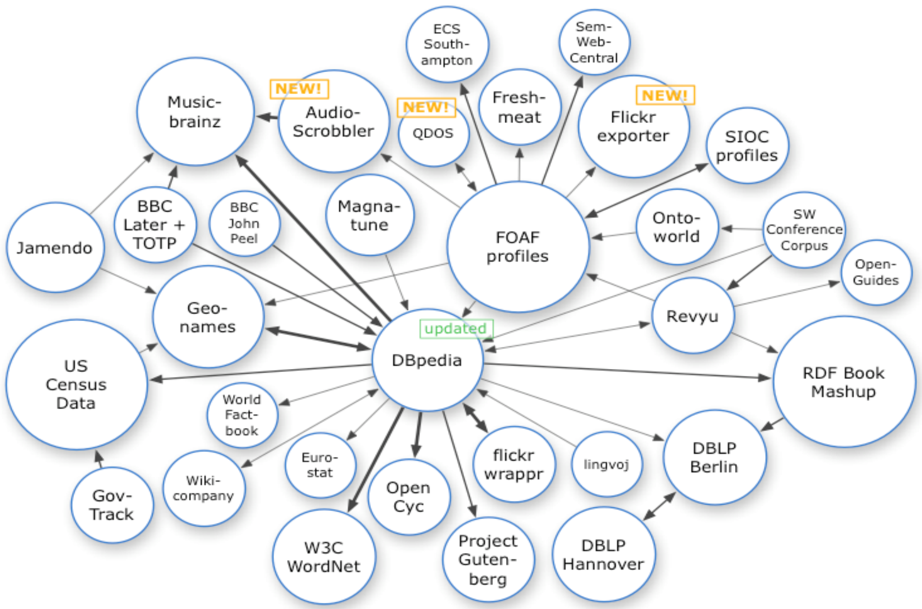
- Best practices to publish data on the Web
- To avoid the use of URIs as plain identifiers
  - A pattern very common when designing OWL ontologies
  - URIs were mainly used as identifiers
  - When dereferencing such URIs no useful information was retrieved
  - It was breaking the idea of the web as an interlinked space

LOD (2007)



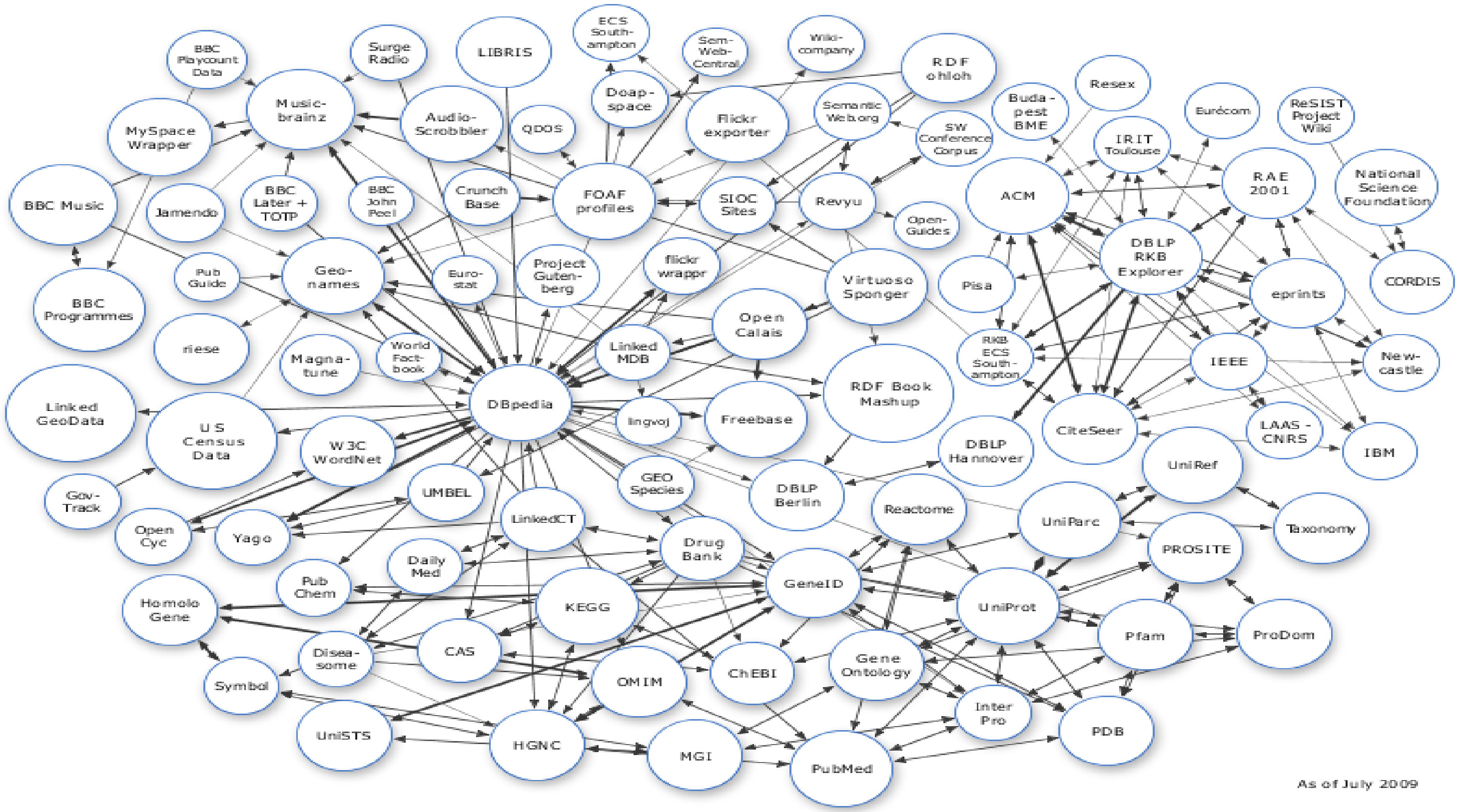
Evolución: https://lod-cloud.net/

LOD (2008)



ECS Southampton
Sem-Web-Central
Music-brainz
NEW!
Audio-Scrobbler
NEW!
QDOS
Fresh-meat
NEW!
Flickr exporter
SIOC profiles
BBC Later + TOTP
BBC John Peel
Magna-tune
FOAF profiles
Onto-world
SW Conference Corpus
Jamendo
Open-Guides
Geo-names
Revyu
updated
DBpedia
US Census Data
RDF Book Mashup
World Fact-book
Euro-stat
flickr wrappr
lingvoj
DBLP Berlin
Gov-Track
Wiki-company
Open Cyc
W3C WordNet
Project Guten-berg
DBLP Hannover

LOD (2009)


BBC Playcount Data
Surge Radio
LIBRIS
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Doap-space
Flickr exporter
Semantic Web.org
SW Conference Corpus
Buda-pest BME
Eurécom
ReSIST Project Wiki
IRIT Toulouse
RAE 2001
National Science Foundation
BBC Music
Jamendo
BBC Later + TOTP
BBC John Peel
Crunch Base
FOAF profiles
SIOC Sites
Revyu
ACM
Open-Guides
DBLP RKB Explorer
CORDIS
BBC Programmes
Pub Guide
Geo-names
Euro-stat
Project Guten-berg
flickr wrappr
Virtuoso Sponger
Pisa
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Magna-tune
World Fact-book
Linked MDB
Open Calais
RKB ECS South-ampton
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GEO Species
DBLP Berlin
Reactome
UniRef
UniParc
Taxonomy
Drug Bank
Daily Med
Pub Chem
GeneID
UniProt
PROSITE
Homolo Gene
KEGG
CAS
Disea-some
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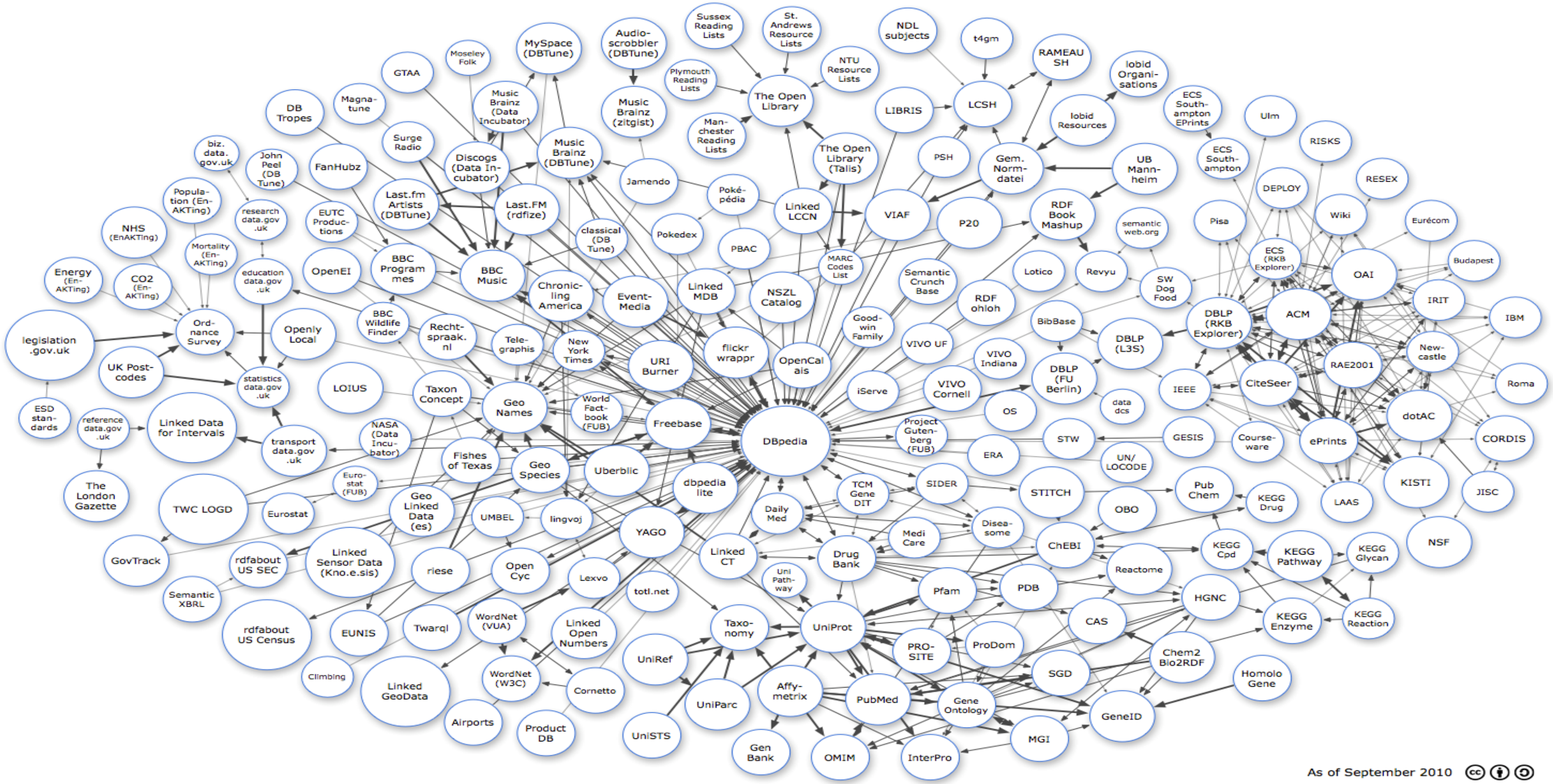
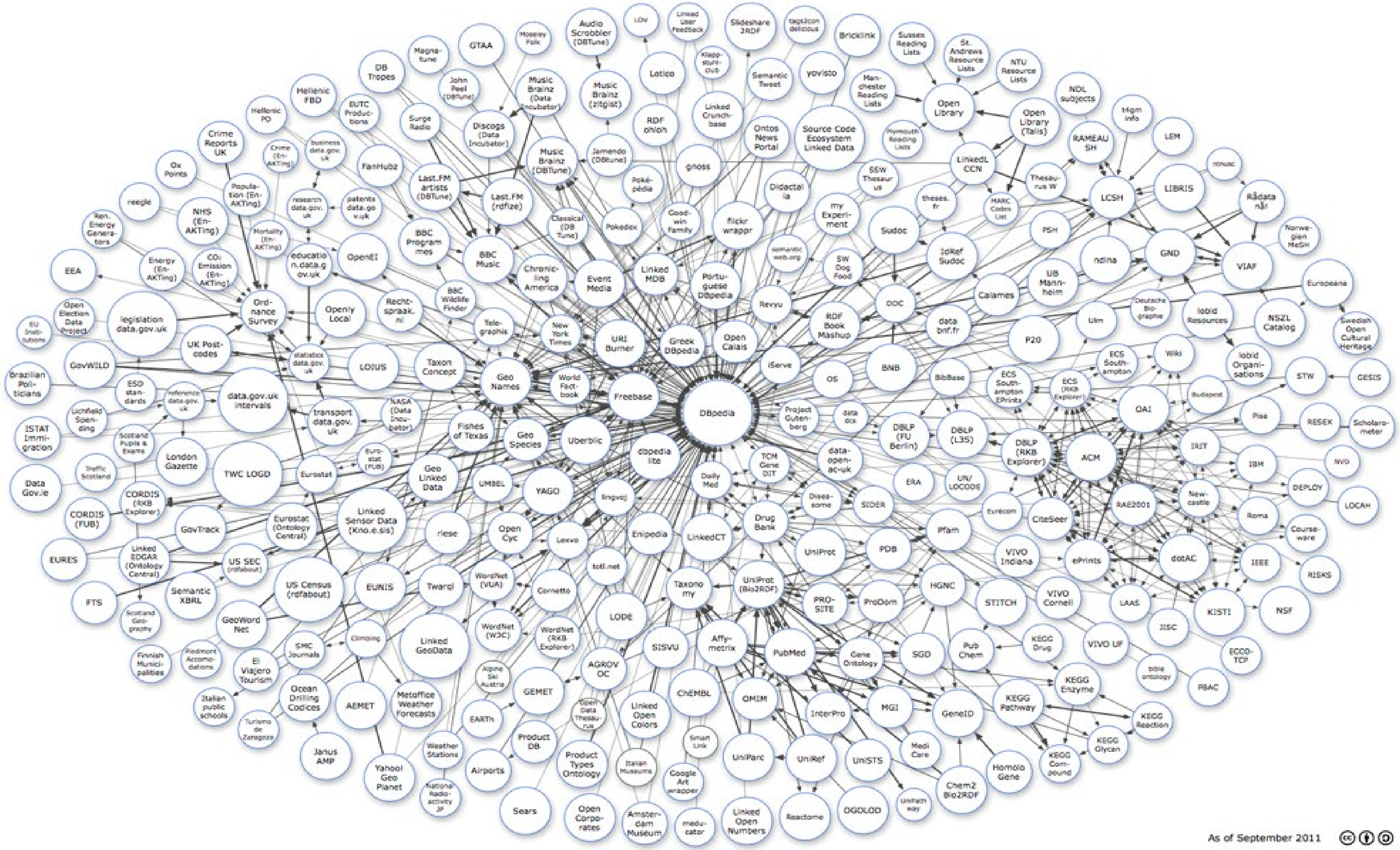
As of July 2009

LOD (2010)



LOD (2011)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Freebase
Geo Names
URI Burner
Greek DBpedia
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dbpedia lite
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Event Media
Portuguese DBpedia
Flickr wrappr
Pokedex
Music Brainz (DBTune)
Last.FM (rdfize)
Last.FM artists (DBTune)
BBC Music
BBC Program mes
BBC Wildlife Finder
Chronicling America
New York Times
World Fact-book
Taxon Concept
LOIUS
Openly Local
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London Gazette
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Linked Sensor Data (Kno.e.sis)
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El Viajero Tourism
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Ocean Drilling Codices
Yahoo! Geo Planet
Janus AMP
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EURES
FTS
GovWILD
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ISTAT Immi-gration
Data Gov.ie
CORDIS (FUB)
CORDIS (RKB Explorer)
Linked EDGAR (Ontology Central)
reegle
NHS (En-AKTing)
Crime Reports UK
Hellenic FBD
Hellenic PD
DB Tropes
Magna-tune
GTAA
Audio Scrobbler (DBTune)
LOV
Slideshare 2RDF
Bricklink
Sussex Reading Lists
Open Library
Open Library (Talis)
LCSH
LIBRIS
VIAF
GND
ndlna
Europeana
NSZL Catalog
P20
BNB
DDC
Sudoc
Calames
data bnf.fr
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DBLP (FU Berlin)
DBLP (L3S)
DBLP (RKB Explorer)
ACM
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dotAC
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VIVO Cornell
VIVO UF
ECCO-TCP
PBAC
Drug Bank
Diseasome
SIDER
Daily Med
TCM Gene DIT
LinkedCT
UniProt
UniProt (Bio2RDF)
PDB
Pfam
ProDom
PRO-SITE
HGNC
STITCH
PubMed
Gene Ontology
SGD
Pub Chem
KEGG Drug
KEGG Enzyme
KEGG Pathway
KEGG Reaction
KEGG Glycan
KEGG Compound
Homolo Gene
Chem2 Bio2RDF
GeneID
MGI
InterPro
UniRef
UniSTS
UniParc
OMIM
CHEMBL
Reactome
OGOLOD
Linked Open Numbers
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SISVU
Taxono my
LODE
AGROV OC
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Product DB
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Amster-dam Museum
Airports
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Lexvo
lingvoj
Enipedia
totl.net
Cornetto
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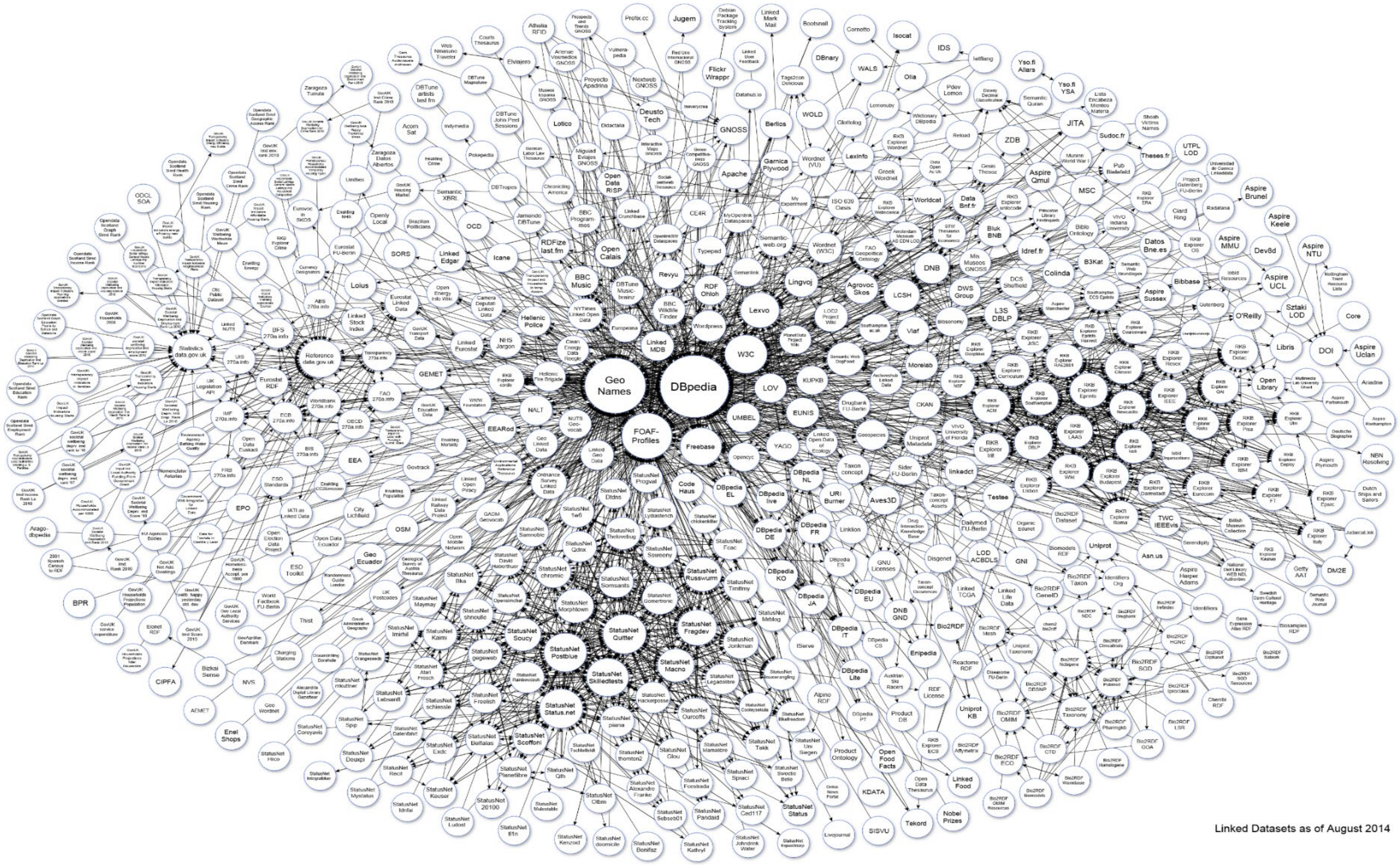
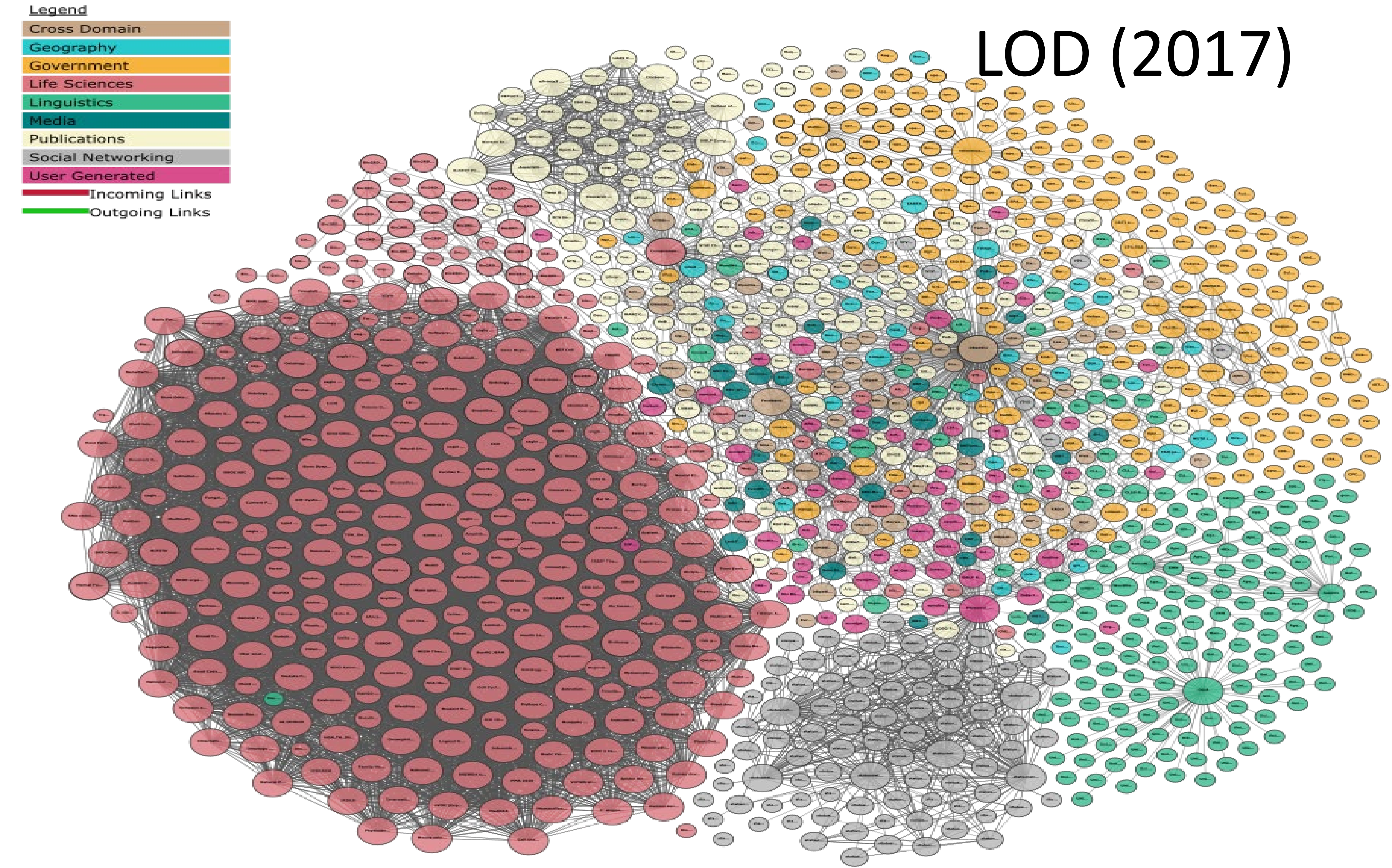
Geo Linked Data
Fishes of Texas
As of September 2011

LOD (2014)



Linked Datasets as of August 2014

LOD (2017)


Legend
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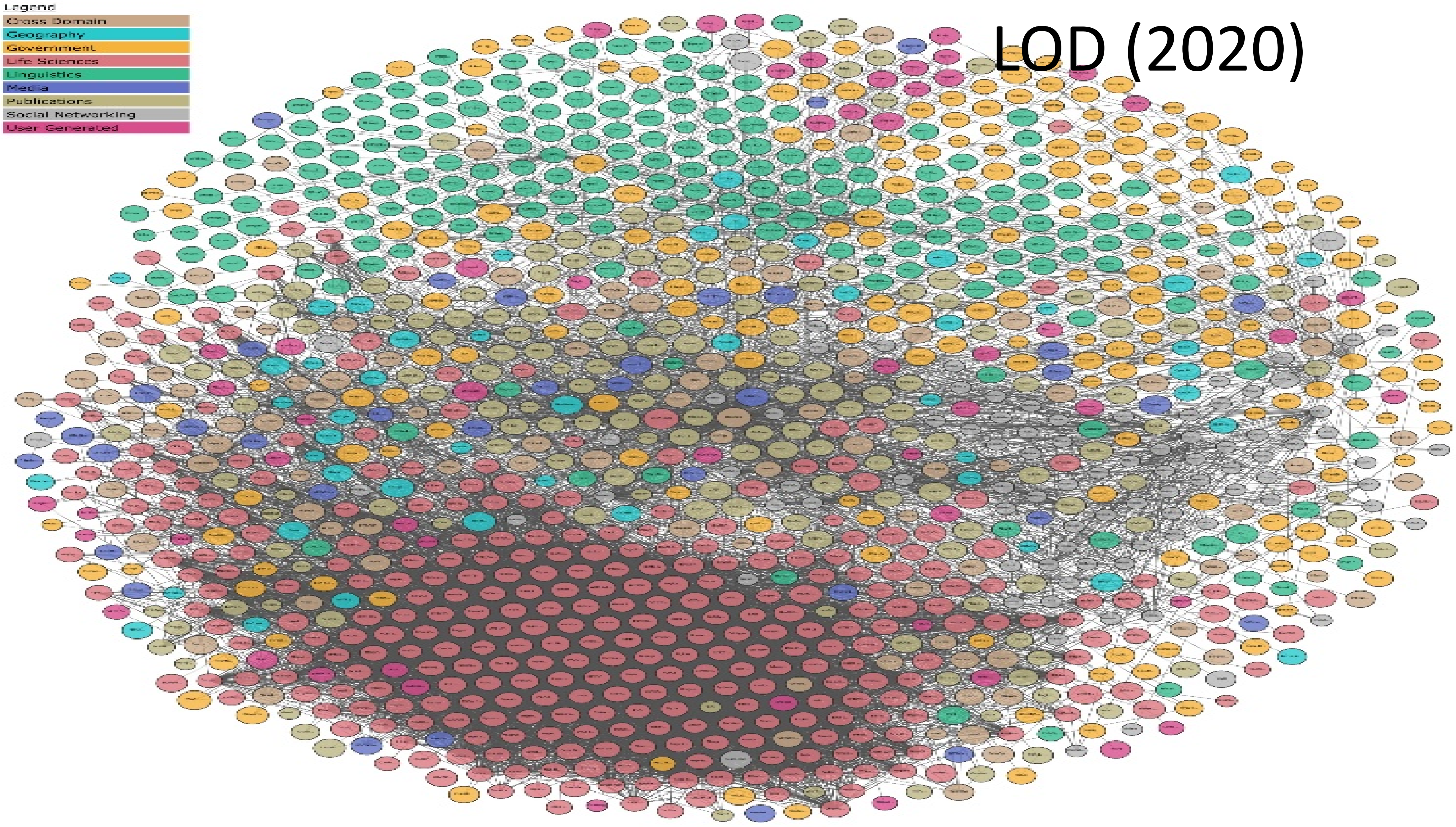
Geography
Government
Life Sciences
Linguistics
Media
Publications
Social Networking
User Generated
Incoming Links
Outgoing Links

LOD (2020)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Media
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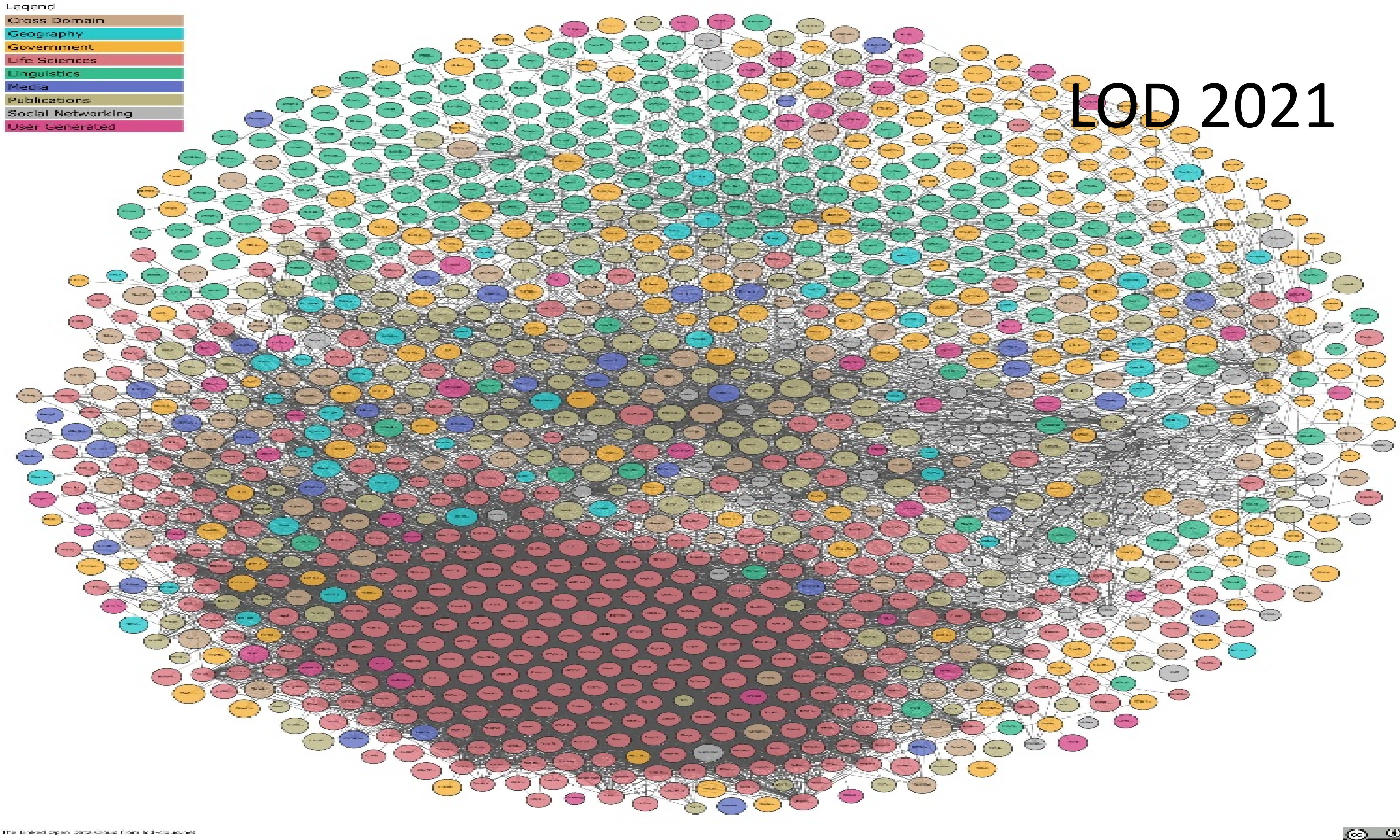
LOD 2021


Legend
Cross Domain
Geography
Government
Life Sciences
Linguistics
Media
Publications
Social Networking
User Generated

Knowledge Graphs

Knowledge graph = a **graph of data** intended to represent knowledge about some domain

Nodes represent entities of interest

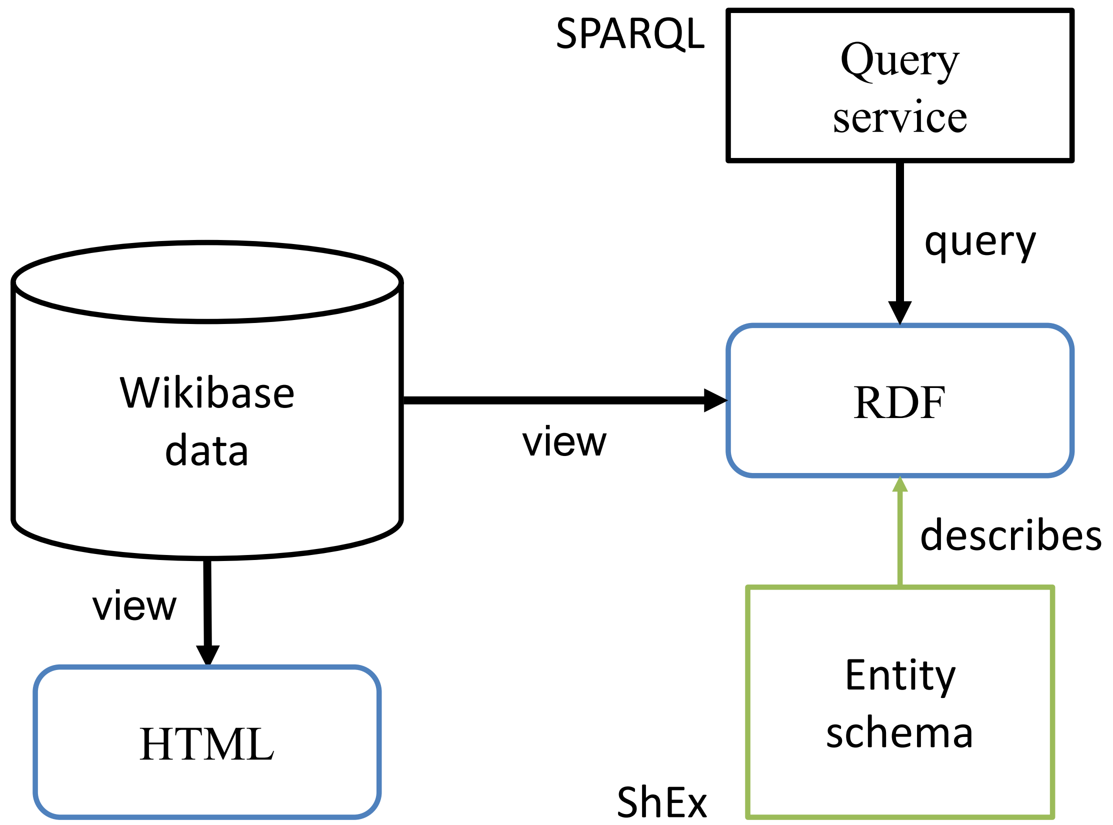
Edges represent relations between these entities

Popularized by Google in 2012

Different types of knowledge graphs models

- RDF based
- Property graphs
- Wikibase graphs

Overview


SPARQL
Query service
query
Wikibase data
view
RDF
describes
view
HTML
Entity schema
ShEx