

# Semantic Web Technologies

Topic: RDF and Linked Data

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# Overview

- Basic concepts of RDF
- Formats for serializing RDF data
- Advanced features of RDF
- What is Linked Data?



# RDF: Basic Concepts

# RDF in General

- Resource Description Framework
- A resource may basically be everything
  - e.g. persons, places, Web documents, abstract concepts
- Descriptions of resources
  - Attributes
  - Relationships
- The framework contains:
  - A data model, and
  - Languages and syntaxes

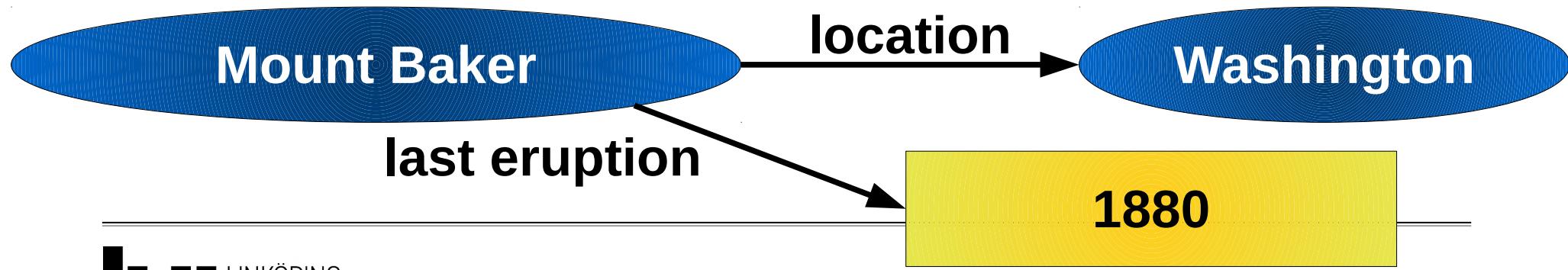


# RDF Data Model

- Data comes as a set of **triples** (subject, predicate, object)
- **Subject:** resources
- **Predicate:** properties
- **Object:** literals or resources
- **Examples:**
  - ( Mount Baker , last eruption , 1880 )
  - ( Mount Baker , location , Washington )

# RDF Data Model (cont'd)

- RDF based data may be understood as a **graph**:
  - Triples as directed edges
  - Subjects and objects as vertices
  - Edges labeled by predicate
- Example:
  - ( Mount Baker , last eruption , 1880 )
  - ( Mount Baker , location , Washington )

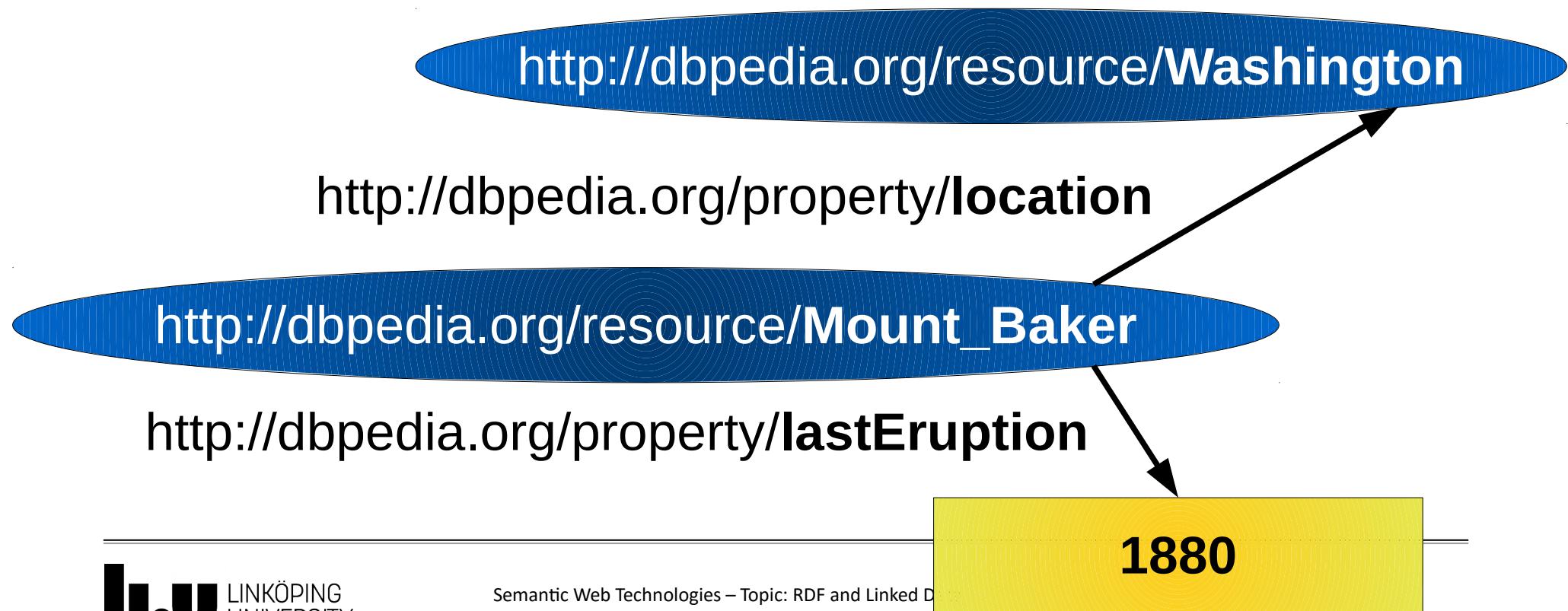


# Uniform Resource Identifier (URI)

- URIs extend the concept of URLs
  - Globally **unique identifier** for resources
  - URL of a Web document usually used as its URI
  - Attention: URIs identify not only Web documents
- Example:
  - Me: <http://olafhartig.de/foaf.rdf#olaf>
  - RDF document about me:  
<http://olafhartig.de/foaf.rdf>
  - HTML document about me:  
<http://olafhartig.de/index.html>

# Example Revisited

- ([http://dbpedia.org/resource/Mount\\_Baker](http://dbpedia.org/resource/Mount_Baker),  
<http://dbpedia.org/property/lastEruption>, 1880)
- ([http://dbpedia.org/resource/Mount\\_Baker](http://dbpedia.org/resource/Mount_Baker),  
<http://dbpedia.org/property/location>,  
<http://dbpedia.org/resource/Washington>)

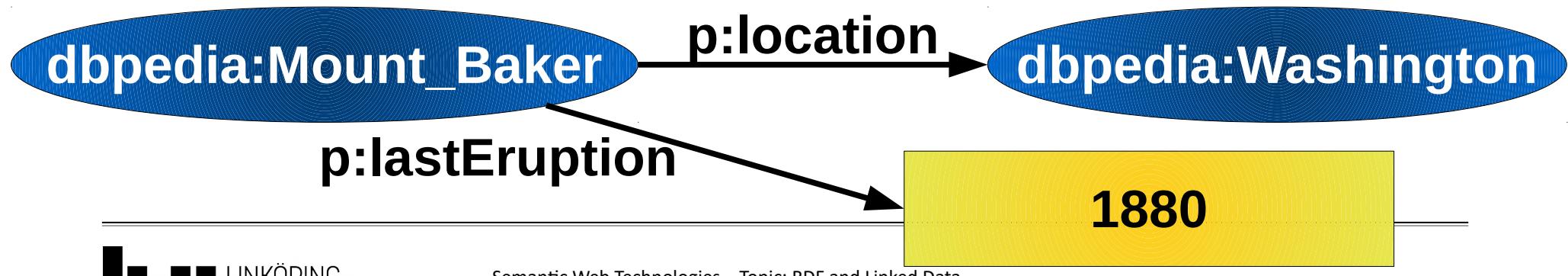


# Compact URI (CURIE)

- Abbreviated Notation for URIs
- Syntax:
  - Prefix name (references a prefix of the URI)
  - Colon character (“：“)
  - Reference part
- URI by concatenating the prefix and the reference part
- Examples:
  - dbpedia:Mount\_Baker for  
[http://dbpedia.org/resource/Mount\\_Baker](http://dbpedia.org/resource/Mount_Baker)
  - myfoaf:olaf for  
 <http://olafhartig.de/foaf.rdf#olaf>

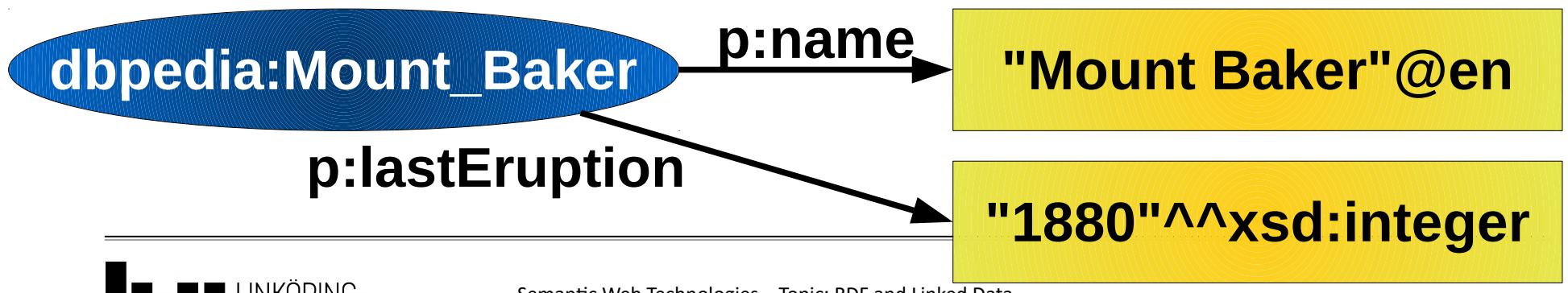
# Example with CURIEs

- Using
  - *dbpedia* for prefix *http://dbpedia.org/resource/*
  - *p* for prefix *http://dbpedia.org/property/*
- we have
  - (dbpedia:Mount\_Baker, p:lastEruption, 1880)
  - (dbpedia:Mount\_Baker, p:location, dbpedia:Washington)



# Literals

- Literals may occur in the object position of RDF triples
- Represented by strings
- Literal strings interpreted by datatypes
  - Datatype identified by a URI
  - Common to use the XML Schema datatypes
  - If no datatype, then interpreted as xsd:string
- Untyped literals may have language tags (e.g. @de)



# RDF Turtle

# Turtle: A Human-Readable Syntax for RDF

- Simple, human-readable notation to list RDF triples:
  - Triples separated by a period (“.”) character
  - Example:

```
<http://dbpedia.org/resource/Mount_Baker>
  <http://dbpedia.org/property/lastEruption>
    "1880"^^xsd:integer .

<http://dbpedia.org/resource/Mount_Baker>
  <http://dbpedia.org/property/location>
    <http://dbpedia.org/resource/Washington> .
```

# CURIEs in Turtle

- @prefix directive binds a prefix to a namespace URI

```
@prefix dbpedia : <http://dbpedia.org/resource/> .  
@prefix p : <http://dbpedia.org/property/> .  
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .  
  
dbpedia:Mount_Baker p:lastEruption "1880"^^xsd:integer .  
dbpedia:Mount_Baker p:location dbpedia:Washington .  
  
dbpedia:Washington p:borderingstates dbpedia:Oregon .  
dbpedia:Washington p:borderingstates dbpedia:Idaho .
```

# Syntactic Sugar in Turtle

- Property lists separated by a semicolon (“;”) character
- Object lists separated by a comma (“,”) character

```
@prefix dbpedia : <http://dbpedia.org/resource/> .  
@prefix p : <http://dbpedia.org/property/> .  
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .  
  
dbpedia:Mount_Baker p:lastEruption "1880"^^xsd:integer ;  
                      p:location      dbpedia:Washington .  
  
dbpedia:Washington p:borderingstates dbpedia:Oregon ,  
                      dbpedia:Idaho .
```

# Some More Syntactic Sugar

- Shortcuts for number literals

```
dbpedia:Mount_Baker p:lastEruption "1880"^^xsd:integer ;  
                      geo:lat "48.777222"^^xsd:float ;  
                      geo:long "-121.813332"^^xsd:float .
```

Equivalent:

```
dbpedia:Mount_Baker p:lastEruption 1880 ;  
                      geo:lat 48.777222 ;  
                      geo:long -121.813332 .
```

# Other Serialization Formats

# N-Triples

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

Turtle

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

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

```
dbpedia:Mount_Baker p:lastEruption "1880"^^xsd:integer .
```

```
dbpedia:Mount_Baker p:location dbpedia:Washington .
```

```
<http://dbpedia.org/resource/Mount_Baker> <http://dbpedia.org/property/lastEruption> "1880"^^<http://www.w3.org/2001/XMLSchema#integer> .
```

```
<http://dbpedia.org/resource/Mount_Baker> <http://dbpedia.org/property/location> <http://dbpedia.org/resource/Washington> .
```

N-Triples

- One line per triple

# RDF/XML: An XML Syntax for RDF

```
@prefix dbpedia: <http://dbpedia.org/resource/> .  
@prefix p: <http://dbpedia.org/property/> .  
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .  
  
dbpedia:Mount_Baker p:lastEruption "1880"^^xsd:integer .  
dbpedia:Mount_Baker p:location dbpedia:Washington .
```

Turtle

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"  
          xmlns:p="http://dbpedia.org/property/">\n  
<rdf:Description rdf:about="http://dbpedia.org/resource/Mount_Baker">\n    <p:lastEruption>\n        <rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">\n            >1880</p:lastEruption>\n        <p:location rdf:resource="http://dbpedia.org/resource/Washington"/>\n    </rdf:Description>\n</rdf:RDF>
```

RDF/XML

# RDFa: RDF inside HTML Documents

```
@prefix dbpedia: <http://dbpedia.org/resource/> .  
@prefix p: <http://dbpedia.org/property/> .  
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .  
  
dbpedia:Mount_Baker p:lastEruption "1880"^^xsd:integer .  
dbpedia:Mount_Baker p:location dbpedia:Washington .
```

Turtle

```
<div xmlns="http://www.w3.org/1999/xhtml"  
      prefix=" p: http://dbpedia.org/property/  
            rdf: http://www.w3.org/1999/02/22-rdf-syntax-ns#  
            xsd: http://www.w3.org/2001/XMLSchema#">  
  
<div about="http://dbpedia.org/resource/Mount_Baker">  
    <div property="p:lastEruption" datatype="xsd:integer">1880</div>  
    <div rel="p:location" resource="http://dbpedia.org/resource/Washington">  
    </div>  
  </div>  
</div>
```

HTML with RDFa Markup

# JSON-LD

```
@prefix dbpedia: <http://dbpedia.org/resource/> .  
@prefix p: <http://dbpedia.org/property/> .  
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .  
  
dbpedia:Mount_Baker p:lastEruption "1880"^^xsd:integer .  
dbpedia:Mount_Baker p:location dbpedia:Washington .
```

Turtle

```
{  
  "@context": "http://example.org/mycontext.jsonld",  
  "@id": "http://dbpedia.org/resource/Mount_Baker",  
  "lastEruption": 1880,  
  "location": {  
    "@id": "http://dbpedia.org/resource/Washington"  
  }  
}  
{ "@context": {  
  "lastEruption": "http://dbpedia.org/property/lastEruption",  
  "location": "http://dbpedia.org/property/location" }  
}
```

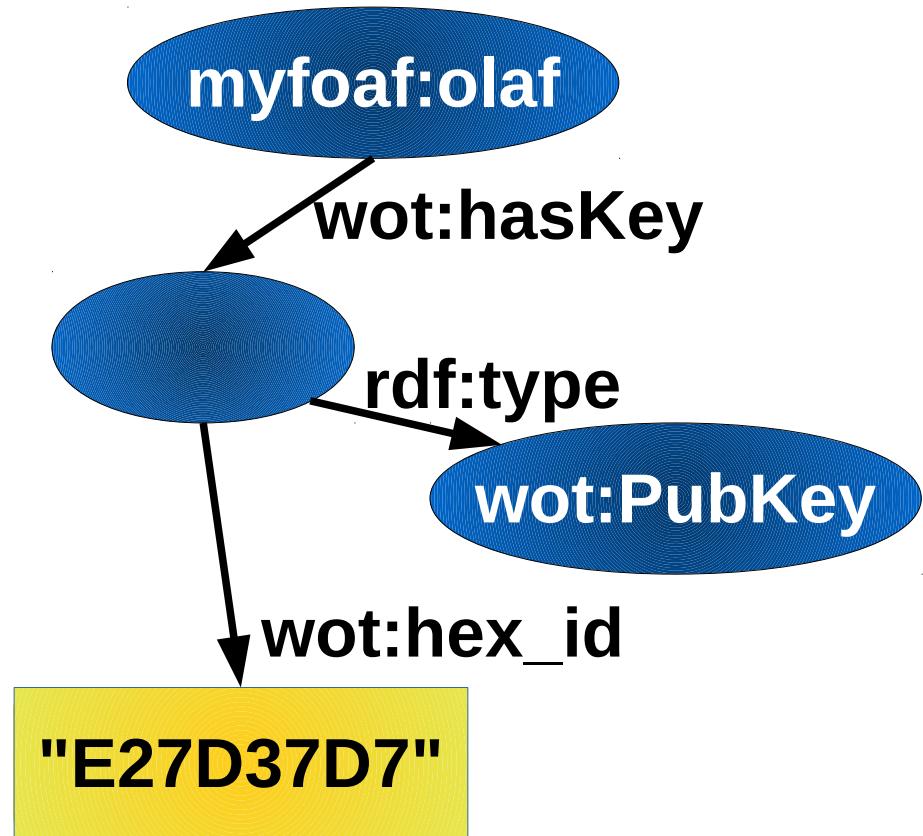
JSON-LD

# RDF: Advanced Features

## Blank Nodes

# Blank Nodes

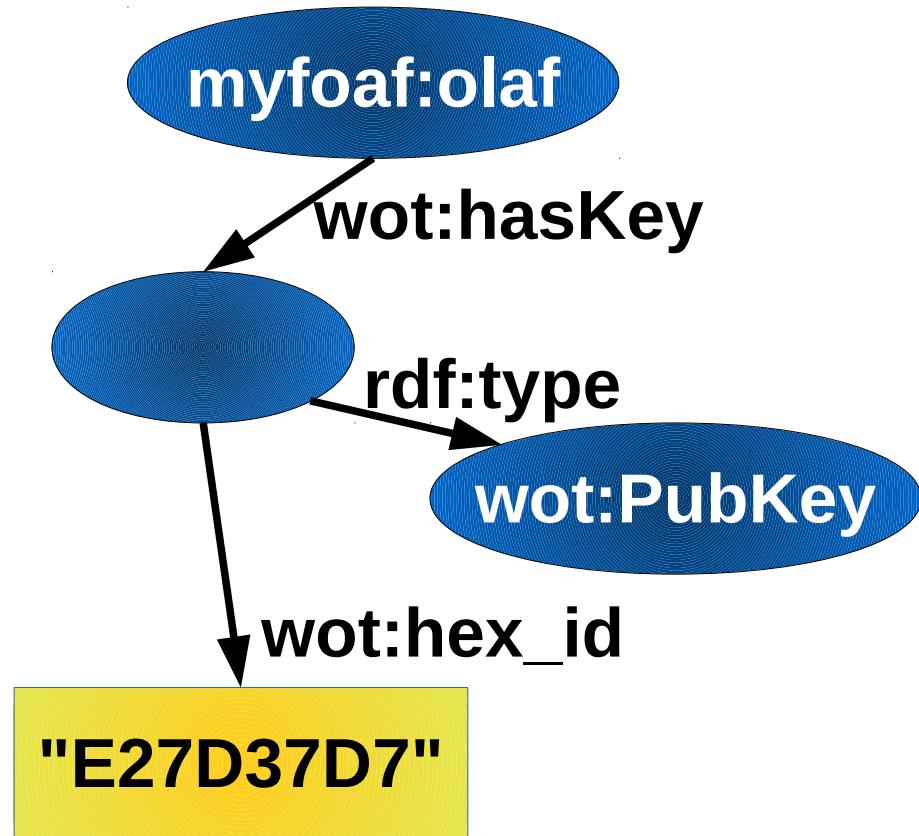
- Unnamed, anonymous nodes
- Resources for which we do not have a URI as identifier, because
  - We may not know the URI
  - There is no point in minting a URI for them



# Blank Node Identifiers

- Needed to denote blank nodes when writing RDF to a file
- Typical form: `_:xyz`
- Example in Turtle:

```
myfoaf:olaf wot:hasKey _:x .  
_:x rdf:type wot:PubKey ;  
    wot:hex_id "E27D37D7" .
```

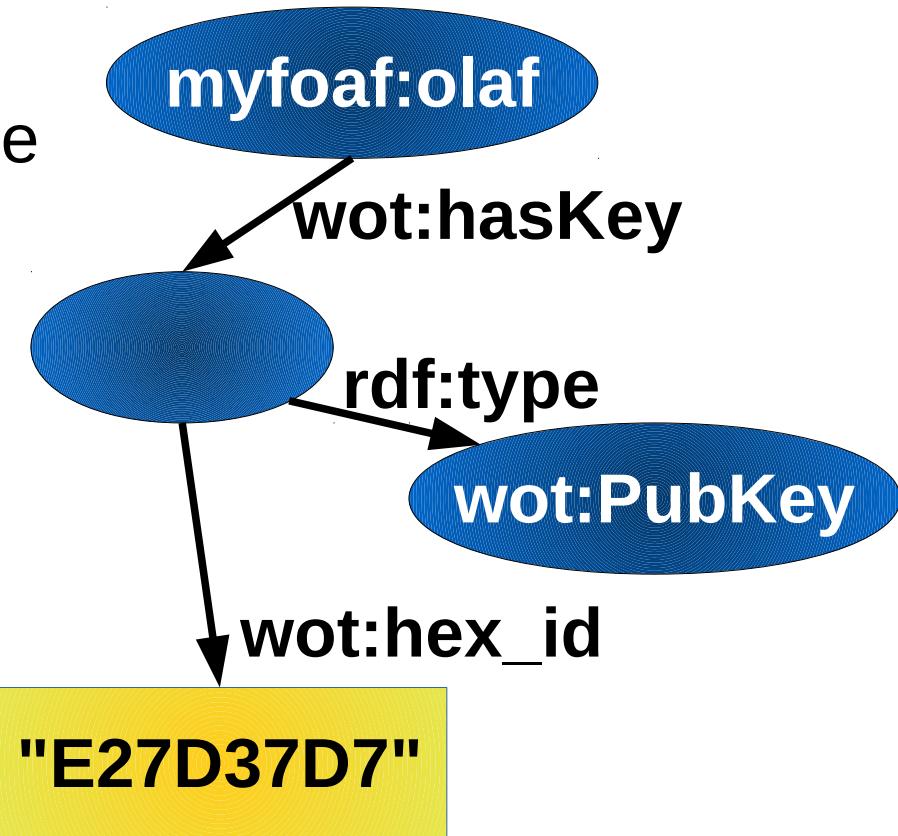


- Scope only within the serialization of a single RDF graph
  - i.e., the same bnode identifier in two different serializations cannot be assumed to denote the same thing

# Abbreviated Syntax for BNodes

- In some cases, blank nodes may be represented in Turtle without an explicit blank node identifier

```
myfoaf:olaf wot:hasKey _:x .  
_:x rdf:type wot:PubKey ;  
    wot:hex_id "E27D37D7" .
```



```
myfoaf:olaf wot:hasKey [ rdf:type wot:PubKey ;  
    wot:hex_id "E27D37D7" ]
```

# RDF: Advanced Features

## Containers and Collections

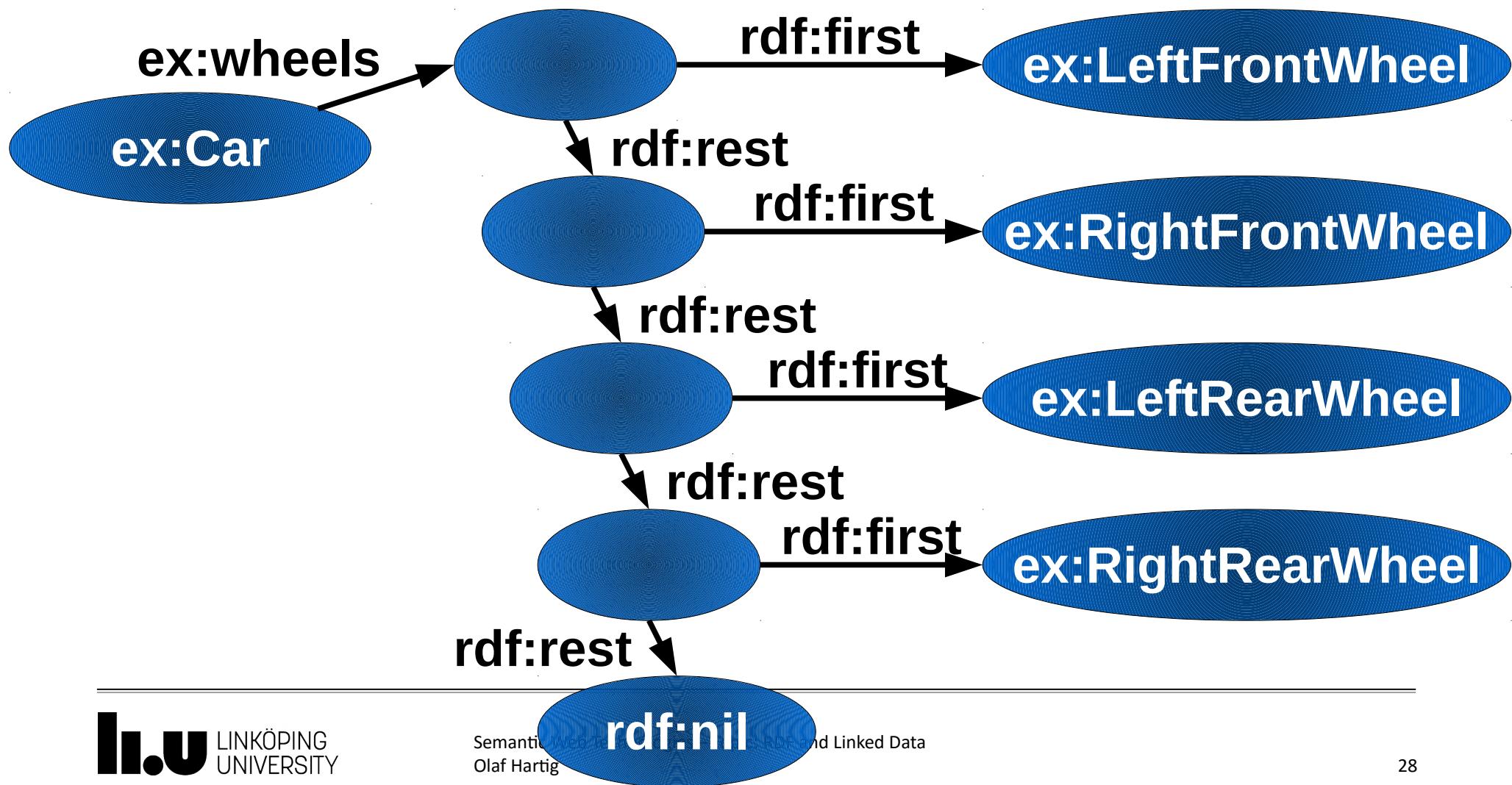
# Containers

- Containers are an open group
- Contain resource or literals, possibly duplicates
  - rdf:Seq – ordered
  - rdf:Bag – unordered
  - rdf:Alt – for alternatives (typical processing will be to select one of the members)

```
dbpedia:Mount_Etna ex:eruptions [ rdf:type rdf:Bag ;  
                                     rdf:_1 "1669" ;  
                                     rdf:_2 "1949" ;  
                                     rdf:_3 "1971" ;  
                                     rdf:_4 "2001" ] .
```

# Collections

- Closed list of resources or literals, possibly duplicates



# Collections in Turtle

- Option 1:

```
ex:Car ex:wheels _:a ;
_:a rdf:first ex:LeftFrontWheel ; rdf:rest _:b .
_:b rdf:first ex:RightFrontWheel ; rdf:rest _:c .
_:c rdf:first ex:LeftRearWheel ; rdf:rest _:d .
_:d rdf:first ex:RightRearWheel ; rdf:rest rdf:nil .
```

- Option 2 (special support for collections in Turtle):

```
ex:Car ex:wheels ( ex:LeftFrontWheel ex:RightFrontWheel
                    ex:LeftRearWheel ex:RightRearWheel ) .
```

# RDF: Advanced Features

## Named Graphs

# Definitions

- **Named graph:** an RDF graph that is associated with a URI
- **RDF dataset:** one default graph + zero or more named graphs

```
dbpedia:Mount_Etna rdfs:seeAlso <http://example.org/d1>.  
dbpedia:Mount_Baker rdfs:seeAlso <http://example.org/d2>.
```

Default  
Graph

```
dbpedia:Mount_Etna http://example.org/d1  
    rdf:type umbel-sc:Volcano ;  
    rdfs:label "Etna" .
```

```
dbpedia:Mount_Baker http://example.org/d2  
    rdf:type umbel-sc:Volcano .
```

```
dbpedia:Beerenberg http://example.org/d3  
    rdf:type umbel-sc:Volcano ;  
    rdfs:label "Beerenberg"@en .
```

# Use Cases

- Maintaining data from different sources separately
- Graph-level metadata (e.g., provenance information)
- Versioning
- Access control
- etc



image source: <http://pngimg.com/download/7778>

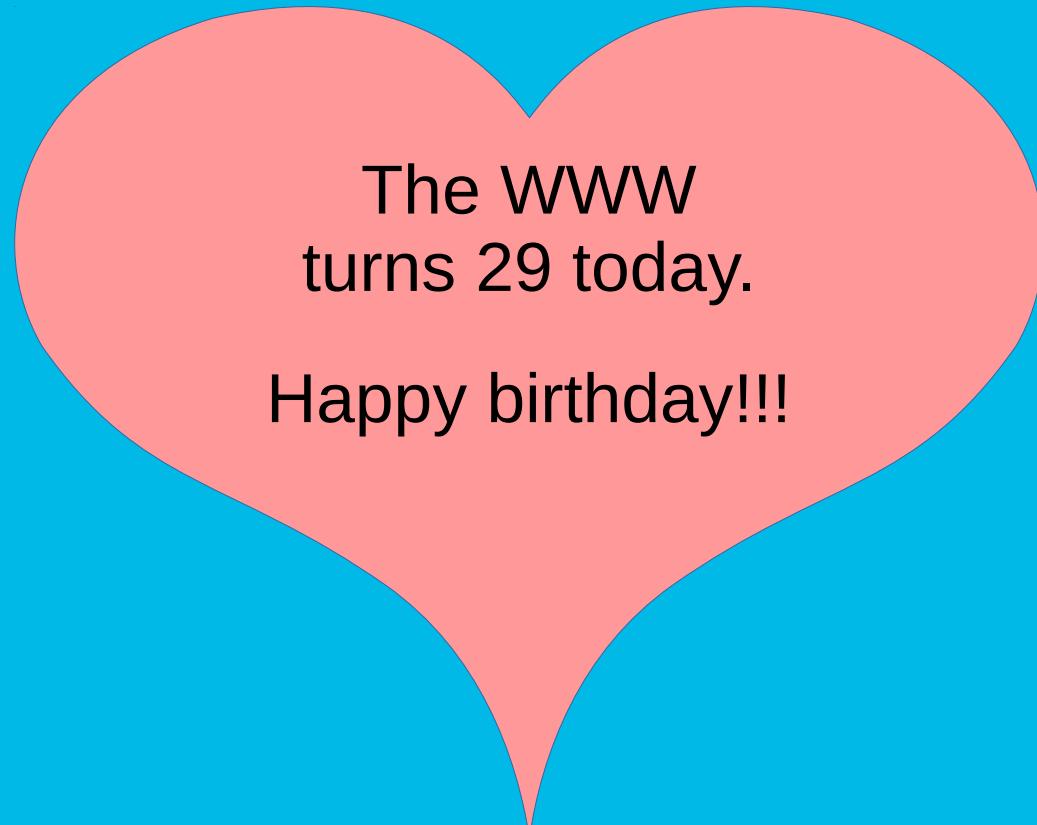
# Serialization Formats

- **TriG**: an extension of Turtle

```
dbpedia:Mount_Etna rdfs:seeAlso <http://example.org/d1>.  
dbpedia:Mount_Baker rdfs:seeAlso <http://example.org/d2>.  
  
GRAPH <http://example.org/d1>  
{ dbpedia:Mount_Etna rdf:type umbel-sc:Volcano ;  
    rdfs:label "Etna" . }  
  
GRAPH <http://example.org/d2>  
{ dbpedia:Mount_Baker rdf:type umbel-sc:Volcano . }  
  
GRAPH <http://example.org/d3>  
{ dbpedia:Beerenberg rdf:type umbel-sc:Volcano ;  
    rdfs:label "Beerenberg"@en . }
```

# Serialization Formats (cont'd)

- **TriG**: an extension of Turtle
- **N-Quads**: like N-Triples, with a fourth element added
- **JSON-LD**: @graph keyword



The WWW  
turns 29 today.

Happy birthday!!!

# Linked Data

# Data on the Web

The screenshot shows the IMDb website for the TV show "War Child (1999)". The page includes a navigation bar with links like "NOW PLAYING", "MOVIE / TV NEWS", "MY MOVIES", "DVD & BLU-RAY", "IMDb TV", "MESSAGE BOARDS", "SHOWTIMES & TICKETS", and "IMDbPro". Below the bar are links to "Home", "Top Movies", "Photos", "Independent Film", "GameBase", "Browse", and "Help". A search bar with the placeholder "search All" and a "go" button is present. The main content area displays the title "War Child (1999) (TV)" with a link to "More at IMDbPro". It shows the user rating as 5 stars (awaiting 5 votes), director Michael Davie, release date 12 July 1999 (USA), genre Documentary | War, tagline "Young people affected by the war in Kosovo", and plot keywords "Spoiler alert! R". On the left sidebar, there are buttons for "Add Poster", "Own the rights?", "Buy it at Amazon", "More at IMDb Pro", "Discuss in Boards", "Add to My Movies", and "Update Data". A "Quicklinks" section includes a dropdown menu for "main details".

Country List

| World Factbook Home

## The World Factbook



**Albania**



**Location:** Southeastern Europe, bordering the Adriatic Sea and Ionian Sea, between Greece in the south and Montenegro and Kosovo to the north

**Geographic coordinates:** 41 00 N, 20 00 E

**Map references:** Europe

**Area:** *total: 28,748 sq km  
land: 27,398 sq km  
water: 1,350 sq km*

**Area - comparative:** slightly smaller than Maryland

**Land boundaries:** *total: 717 km  
border countries: Greece 282 km, Macedonia 151 km, Montenegro 172 km, Kosovo 112 km*

**Coastline:** 362 km

**Maritime claims:** *territorial sea: 12 nm  
continental shelf: 200 m depth onto the deep sea*



Add Poster

Own the rights?

Buy it at Amazon

More at IMDb Pro

Discuss in Boards

Add to My Movies

Update Data

Quicklinks

main details

Top Links

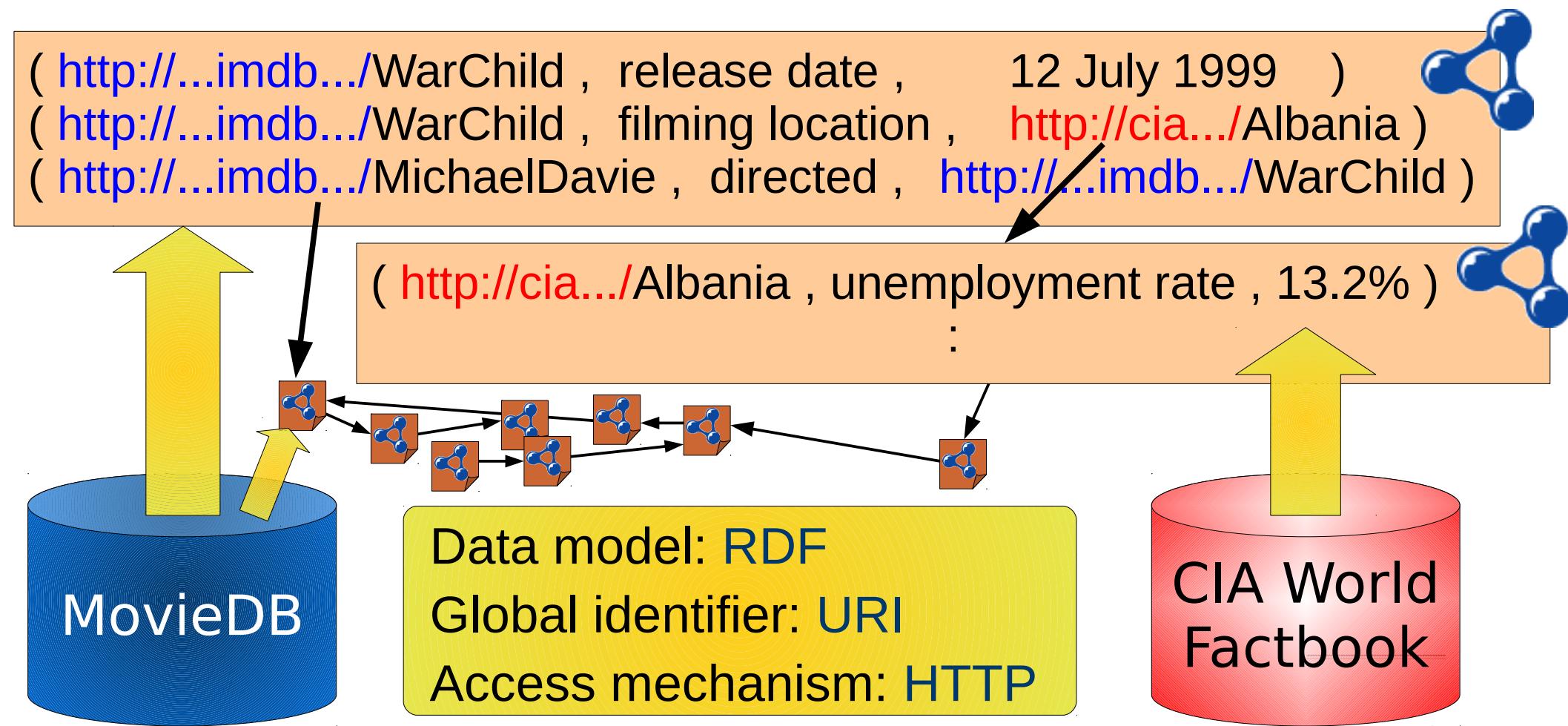
MovieDB

Traditionally, published in HTML documents that are designed for human consumption

CIA World Factbook

# Linked Data Publishing Principles

- Goal: publishing structured data on the WWW in a standardized, machine-readable manner



# Adoption

- Started as a grassroots community effort in 2007
  - Publish existing, open license datasets as Linked Data
  - Interlink things between different data sources
- Prominent publishers joined the effort
  - e.g., BBC, NY Times, Library of Congress, Thomson Reuters, Springer, Nature, Best Buy, Sears, Renault, UK Government
- Numbers
  - BTC 2014 Crawl (February – June 2014):  
ca. 4.1B triples in ca. 44M docs from ca. 48K sites
  - Iodstats (as of September 24, 2017):  
ca. 149B triples in ca. 3.0K datasets



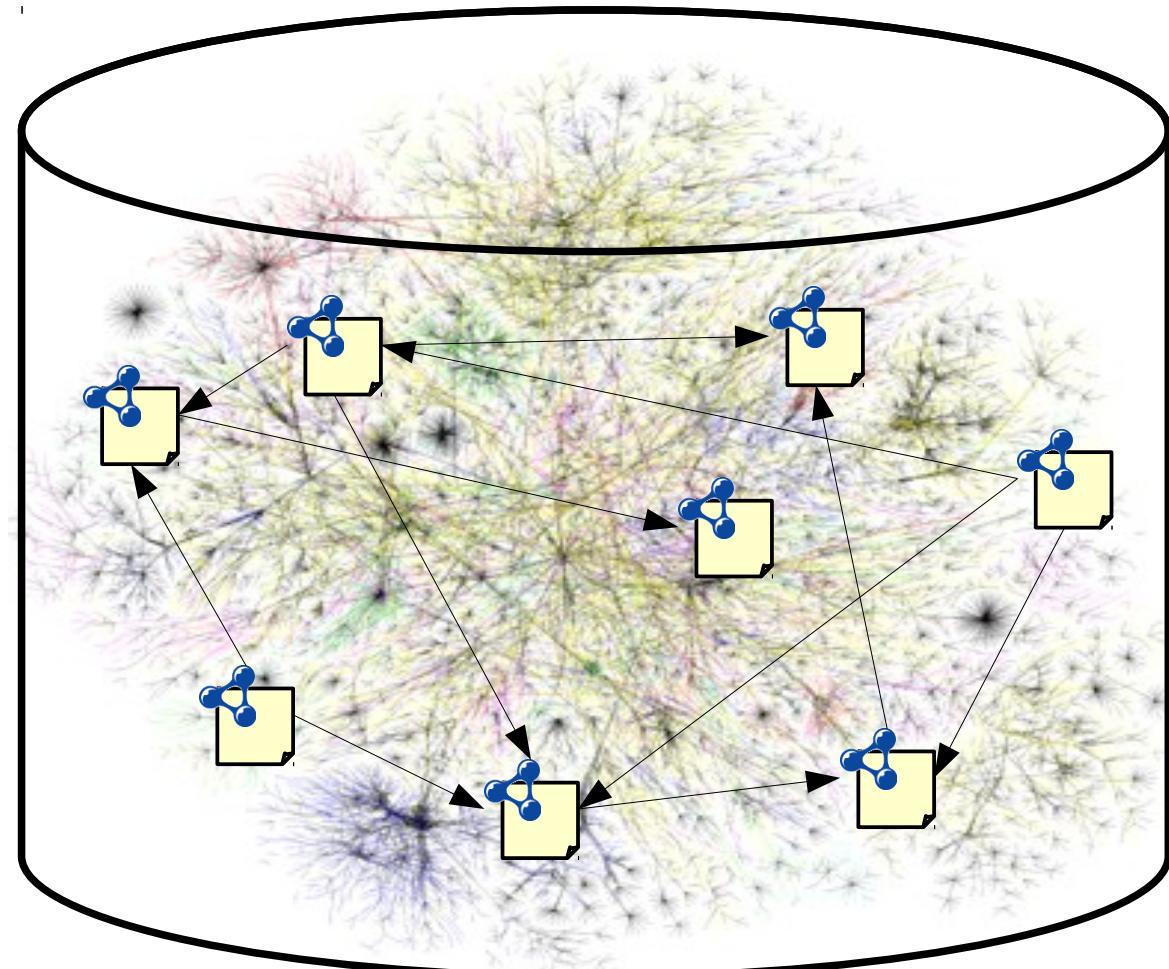
# The Web of Linked Data

**...a globally distributed network of data**

**...which we may understand as a huge distributed database**

**How do we enable applications to query this data?**

- Active area of research!
- Looking for a thesis topic in this area?  
Contact me!



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