



Lebanese University

Faculty of Information 1

Data Science Departement

3rd year – **Social Network Analysis**

Spring – 2021 – Introduction to Knowledge Graphs

Agenda

Introduction: What are Knowledge Graphs?

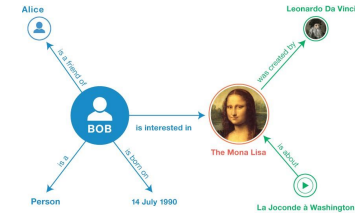
Examples and Applications

- Wikidata
- Cultural Heritage
- Industrial Applications

Standards and Principles

metaphactory Knowledge Graph Platform

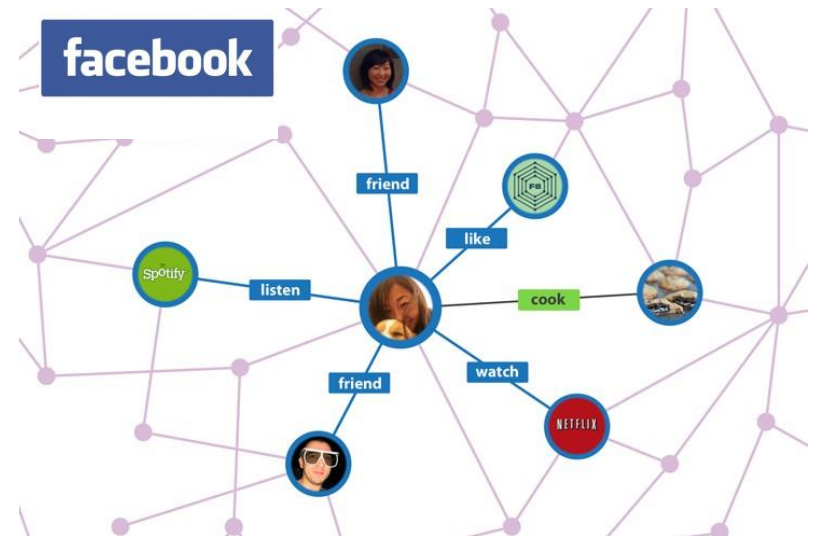
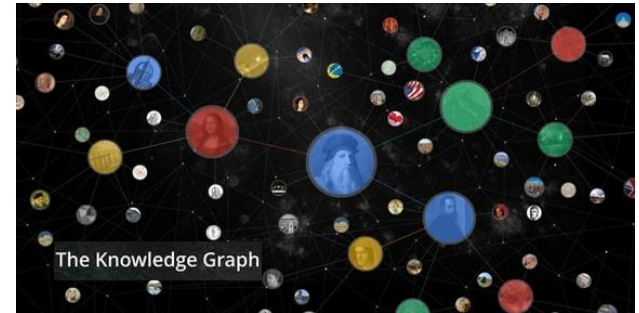
Hands-on Exercises



Introduction

What are Knowledge Graphs?

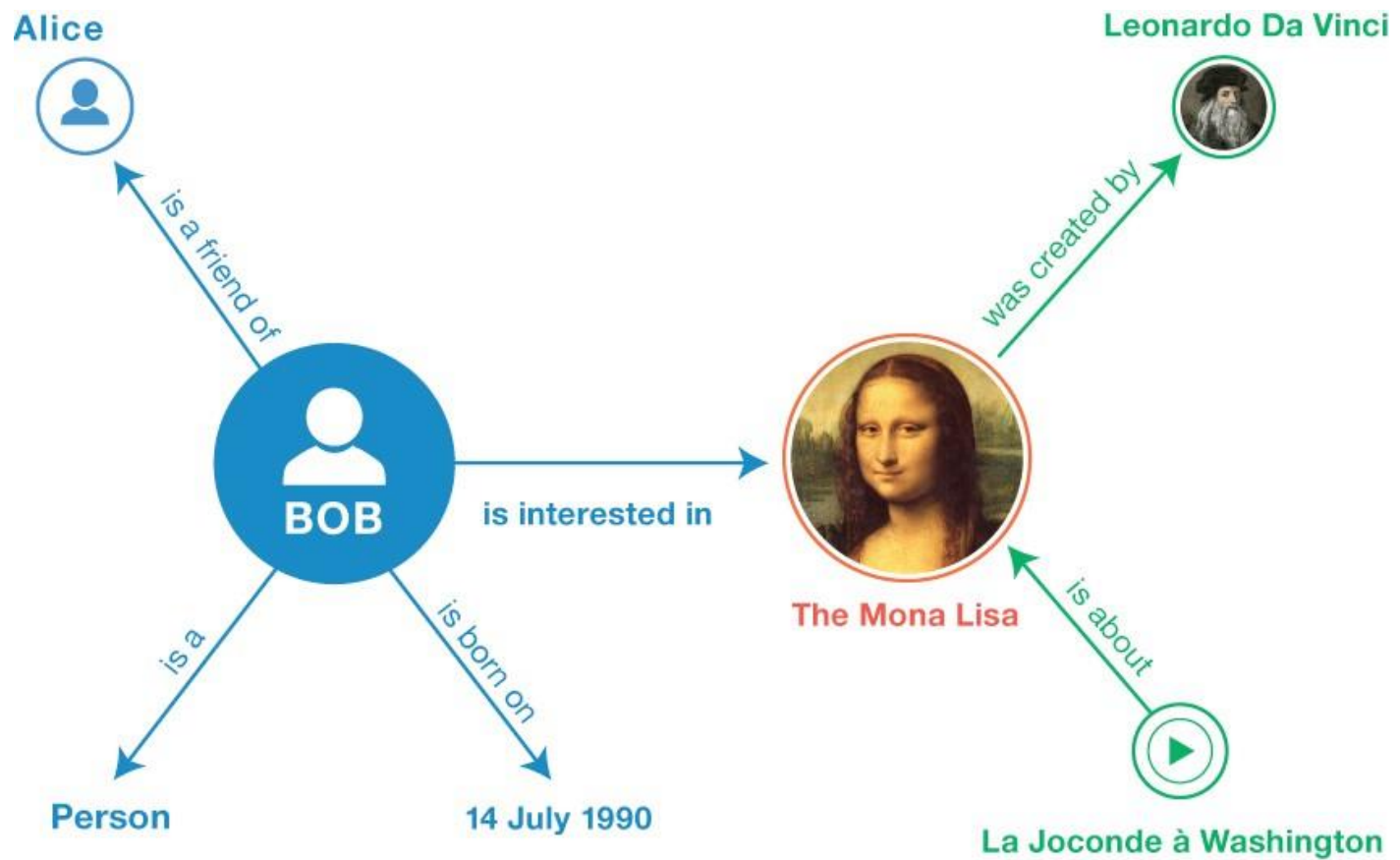
The Rise of Knowledge Graphs



Why (Knowledge) Graphs?

- We need a structured and formal representation of knowledge
- We are surrounded by entities, which are connected by relations
- Graphs are a natural way to represent entities and their relationships
- Graphs can be managed efficiently

A (very small) Knowledge Graph



<http://www.w3.org/TR/2014/NOTE-rdf11-primer-20140225/example-graph.jpg>

What are Knowledge Graphs?

- **Semantic descriptions of entities and their relationships**
- **Uses a knowledge representation formalism**
(Focus here: RDF, RDF–Schema, OWL)
- **Entities:** real world objects (things, places, people) and abstract concepts (genres, religions, professions)
- **Relationships:** graph–based data model where relationships are first–class
- **Semantic descriptions:** types and properties with a well–defined meaning (e.g. through an ontology)
- Possibly axiomatic knowledge (e.g. rules) to support automated reasoning

Knowledge Graphs Enabling Intelligent Applications

Applications

- Semantic Search
- Analytics
- Knowledge Sharing
- Question Answering
- Dashboards
- Knowledge Management

Algorithms

- Inferencing
- Entity Recognition
- Text Understanding
- Machine Learning
- Disambiguation
- Recommendations

Knowledge Graph



- Entities
- Relationships
- Semantic Descriptions

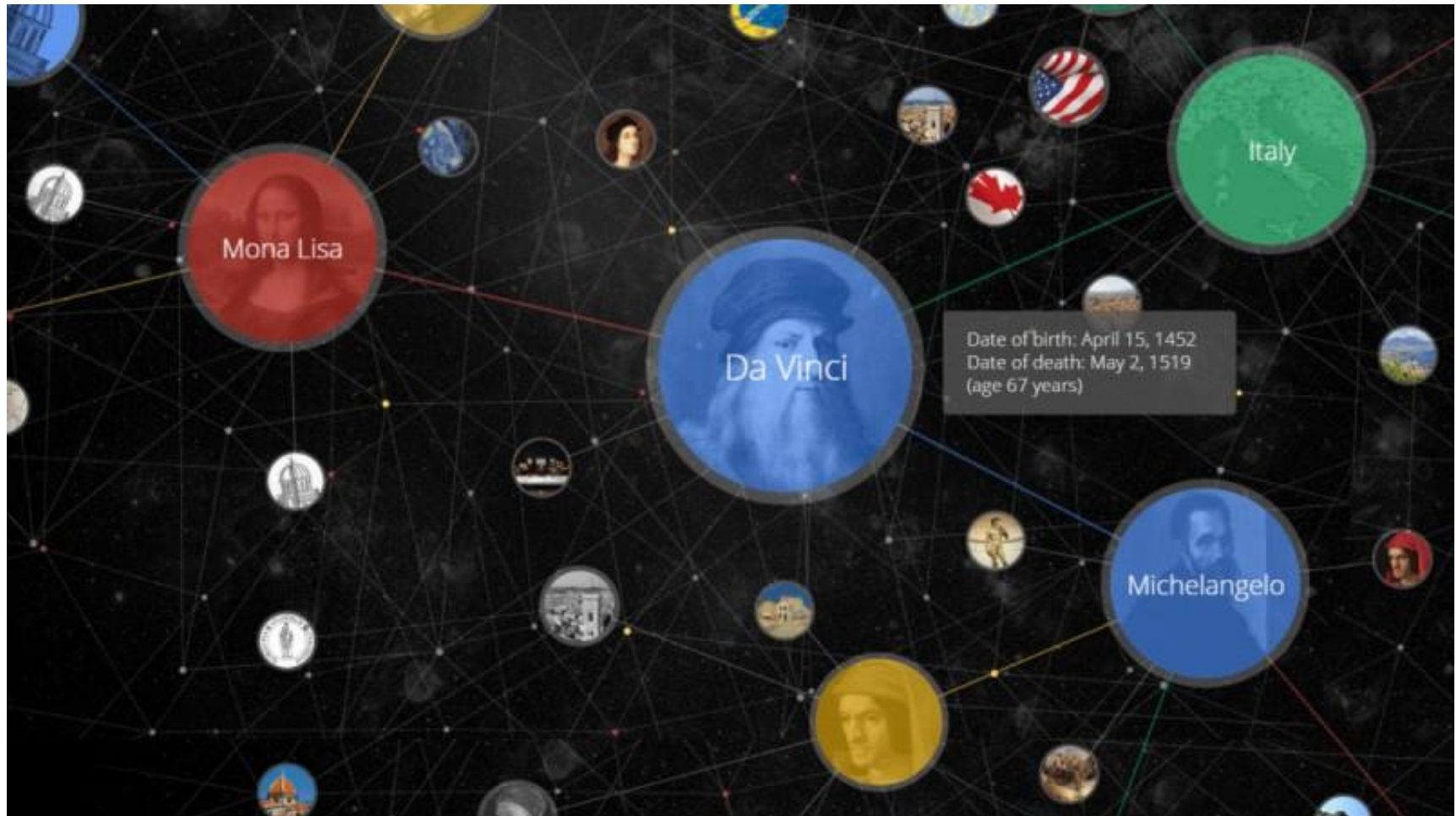
Data Sources

Data Transformation, Integration
Natural Language Processing



Examples and Applications

Google Knowledge Graph



The screenshot shows a Google search for "mona lisa". The search bar contains "mona lisa" and a magnifying glass icon. To the right of the search bar are a grid icon and a "Sign in" button. Below the search bar are navigation tabs: "All", "Images", "Videos", "News", "Maps", "More", and "Search tools". A settings gear icon is in the top right corner. The search results show "About 21,500,000 results (1.11 seconds)".

The search results list several links:

- Mona Lisa - Wikipedia**
https://en.wikipedia.org/wiki/Mona_Lisa ▼
The **Mona Lisa** is a half-length portrait of a woman by the Italian Renaissance artist Leonardo da Vinci, which has been acclaimed as "the best known, the most ...
[Louvre](#) · [Mona Lisa](#) · [Mona Lisa \(disambiguation\)](#) · [The Theft of the Mona Lisa](#)
- Mona Lisa – Portrait of Lisa Gherardini, wife of Francesco del ... - Louvre**
www.louvre.fr/en/.../mona-lisa-portrait-lisa-gherardini-wife-francesco-del-giocondo ▼
The history of the **Mona Lisa** is shrouded in mystery. Among the aspects which remain unclear are the exact identity of the sitter, who commissioned the portrait, ...
- Mona Lisa | painting by Leonardo da Vinci | Britannica.com**
<https://www.britannica.com/topic/Mona-Lisa-painting> ▼
Aug 17, 2016 - **Mona Lisa**, oil painting on a poplar wood panel by the Italian painter, draftsman, sculptor, architect, and engineer Leonardo da Vinci, probably the world's most-famous painting. ... **Mona Lisa**, oil painting on a poplar wood panel by Leonardo da Vinci, A third suggestion was that ...
- Mona Lisa | Leonardo da Vinci | High Renaissance: Florence and ...**
<https://www.khanacademy.org/.../celebrity-art-leonardo-s-mona-l...> ▼
Learn about the history and key elements of the **Mona Lisa**, one of the most famous paintings in the world.
- Is the Mona Lisa Hiding Another Portrait? - artnet News**
<https://news.artnet.com/art-world/leonardo-da-vinci-mona-lisa-portrait-hidden-388235> ▼
Dec 8, 2015 - According to French scientist Pascal Cotte, who has analyzed the painting for over 10 years, da Vinci's '**Mona Lisa**' is hiding another portrait ...




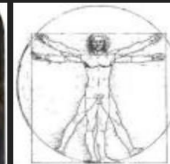
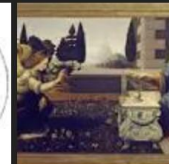





The Knowledge Graph panel on the right features a grid of images of the Mona Lisa. Below the images is the title "Mona Lisa" and a share icon. The description reads: "Work of art". The main text states: "The **Mona Lisa** is a half-length portrait of a woman by the Italian Renaissance artist Leonardo da Vinci, which has been acclaimed as "the best known, the most visited, the most written about, the most ...". A "Wikipedia" link is provided. The panel also lists: "Artist: Leonardo da Vinci", "Dimensions: 77 cm x 53 cm", "Location: The Louvre (since 1797)", "Created: 1503", "Media: Oil paint", and "Periods: High Renaissance, Renaissance".

Discovering Related Entities

Google leonardo da vinci paintings Sign in

All Images Videos Books News More Search tools

Leonardo da Vinci / Artwork Most popular first

 Mona Lisa 1503	 The Last Supper 1498	 The Virgin of the Rocks 1485	 Vitruvian Man	 Annunciation 1472	 Lady with an Ermine 1490	 Adoration of the Magi 1481	 St. John the Baptist 1513	 The Virgin and Child with St. Anne	 The Battle of Anghiari 1505
--	--	--	--	--	--	--	---	---	---

List of works by Leonardo da Vinci - Wikipedia

https://en.wikipedia.org/wiki/List_of_works_by_Leonardo_da_Vinci

The **Last Supper** is Leonardo da Vinci's most famous work of religious art and his only surviving mural. Leonardo da Vinci (baptised Leonardo di ser Piero da Vinci) (pronunciation (help·info)), (April 15, 1452 – May 2, 1519) was one of the leading artists of the High Renaissance.

Major extant works · Disputed attributions · Lost works · Some recent attributions

Leonardo da Vinci - Wikipedia

https://en.wikipedia.org/wiki/Leonardo_da_Vinci

Jump to **Painting** - Leonardo was, and is, renowned primarily as a painter. Among his works, the **Mona Lisa** is the most famous and most parodied portrait and **The Last Supper** the most reproduced religious painting of all time.

Leonardo Da Vinci - The complete works

www.leonardoda-vinci.org/

Leonardo Da Vinci - Homepage. The complete works, large resolution images, ecard, rating, slideshow and more! One of the largest **Leonardo Da Vinci** ...

Biography · Self Portrait · The Works · The Last Supper 1498



Leonardo da Vinci

Mathematician

Leonardo di ser Piero da Vinci, more commonly Leonardo da Vinci or simply Leonardo, was an Italian polymath whose areas of interest included invention, painting, sculpting, architecture, science, music, ... [Wikipedia](#)


Google

All Images News Videos Shopping More Search tools

About 2,960,000 results (0.97 seconds)

Leonardo da Vinci / Born

April 15, 1452, Anchiano



 **Michelangelo**
March 6, 1475

 **Leonardo DiCaprio**
November 11, 1974

 **William Shakespeare**
April 1564

[Feedback](#)

People also ask

- How old was Leonardo da Vinci when he died?
- What did Leonardo da Vinci do?
- Why is Leonardo da Vinci well known?
- What things did Leonardo da Vinci study?

Leonardo da Vinci

Mathematician

Leonardo di ser Piero da Vinci, more commonly Leonardo da Vinci or simply Leonardo, was an Italian polymath whose areas of interest included invention, painting, sculpting, architecture, science, music, ... [Wikipedia](#)

Born: April 15, 1452, [Anchiano](#)

Died: May 2, 1519, [Clos Lucé, Amboise, France](#)

Buried: [Chapel of Saint-Hubert](#)

Siblings: [Giovanni Ser Piero](#), [Guglielmo Ser Piero](#), [more](#)

Quotes

[View 7+ more](#)

Simplicity is the ultimate sophistication.

As a well-spent day brings happy sleep, so a life well spent brings happy death.

Learning never exhausts the mind.

Artwork

[View 15+ more](#)



Knowledge Graph Search API



Get Started

[Introduction](#)

Prerequisites

How To...

Install Client Libraries

Authorize Requests

Use the Knowledge Graph Search Widget

Terms of Service

Google Knowledge Graph Search API



The Knowledge Graph Search API lets you find entities in the [Google Knowledge Graph](#). The API uses standard [schema.org](#) types and is compliant with the [JSON-LD](#) specification.

Contents

Typical use cases

Sample request

Knowledge Graph entities

Typical use cases

Some examples of how you can use the Knowledge Graph Search API include:

- Getting a ranked list of the most notable entities that match certain criteria.
- Predictively completing entities in a search box.
- Annotating/organizing content using the Knowledge Graph entities.

★ **Note:** The Knowledge Graph Search API is a read-only API.

For detailed information about the API methods and parameters, see the [API Reference](#).

Sample request

The following example shows one kind of request you can send to the API. (But check the [Prerequisites](#) section first. You'll also need to insert your own API key.)

<https://developers.google.com/knowledge-graph/>



THE ECONOMIC GRAPH



Examples and Applications

Wikidata

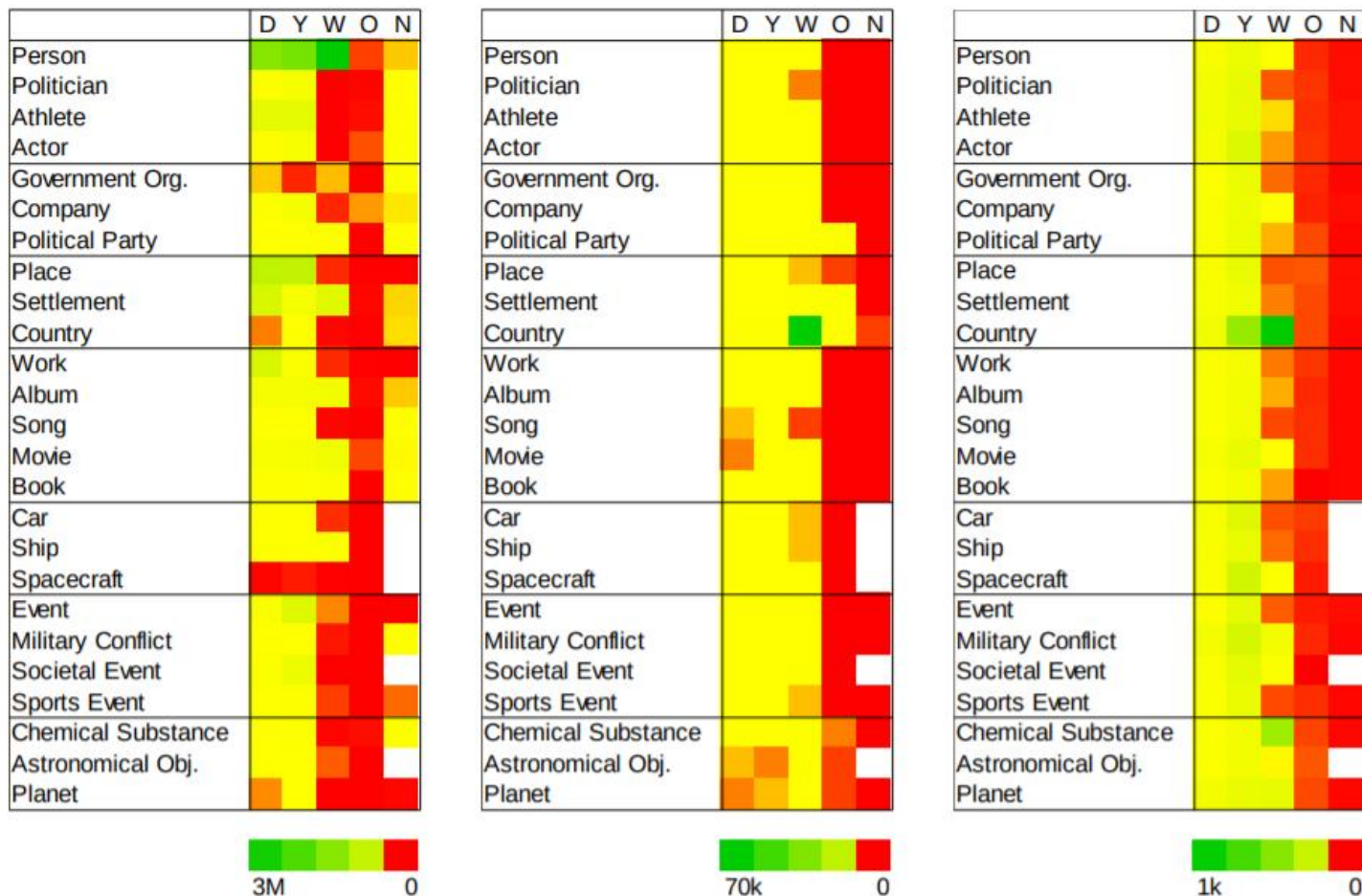
Open Knowledge Graphs



Open Knowledge Graphs

	DBpedia	YAGO	Wikidata	OpenCyc	NELL
Version	2016-04	YAGO3	2016-08-01	2016-09-05	08m.995
# instances	5,109,890	5,130,031	17,581,152	118,125	1,974,297
avg. indegree	13.52	17.44	9.83	10.03	5.33
avg. outdegree	47.55	101.86	41.25	9.23	1.25
# classes	754	576,331	30,765	116,822	290
# relations	3,555	93,659	11,053	165	1,334
Releases	biyearly	> 1 year	live	> 1 year	1-2 days

Open Knowledge Graphs



(a) Number of instances

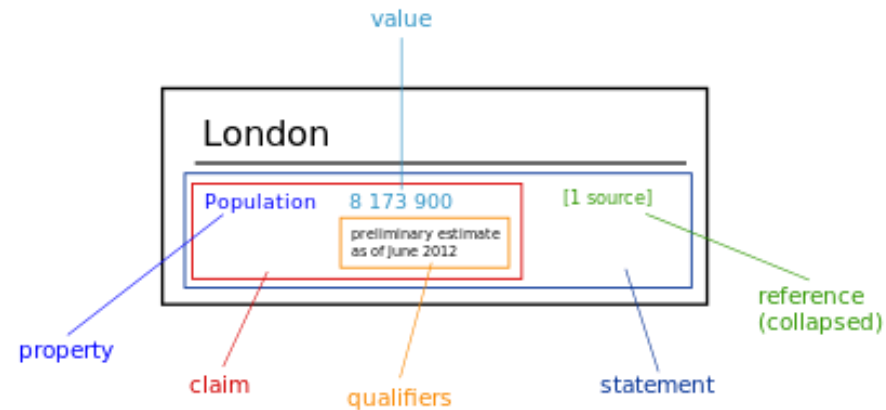
(b) Average indegree

(c) Average outdegree

Fig. 2: Number of instances (a), avg. indegree (b) and avg. outdegree (c) of selected classes. D=DBpedia, Y=YAGO, W=Wikidata, O=OpenCyc, N=NELL. [20]

Wikidata

- **Collecting structured data.** Unlike the Wikipedias, which produce encyclopedic articles, Wikidata collects data, in a structured form.
- **Collaborative.** The data in Wikidata is entered and maintained by Wikidata editors, who decide on the rules of content creation and management in Wikidata supporting the notion of verifiability.
- **Free.** The data in Wikidata is published under the Creative Commons
- **Large.**
 - 25 million entities
 - 130 million statements
 - 130 million labels
 - 350 languages
 - >1500 million triples



London (Q84)

capital city of England and the United Kingdom

London, England | London, UK | London, United Kingdom

► In more languages

[edit]

Statements

topic's main Wikimedia portal	 Portal:London [edit]
	▼ 0 references [add reference]
	[add]

instance of	 metropolitan area [edit]				
	▼ 0 references [add reference]				
	 city with millions of inhabitants [edit]				
	► 1 reference				
	 metropolis [edit]				
	▼ 0 references [add reference]				
	 financial centre [edit]				
	▼ 0 references [add reference]				
	 capital [edit]				
	<table><tr><td>country</td><td>United Kingdom</td></tr><tr><td></td><td>England</td></tr></table>	country	United Kingdom		England
country	United Kingdom				
	England				
	▼ 0 references [add reference]				
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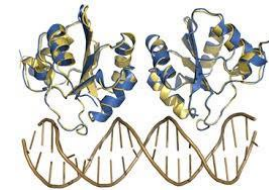
Wikipedia (225 entries) [edit]

[Collapse]

ab	Лондан
ace	London
af	Londen
als	London
am	ላንደን
ang	Lunden
an	Londres
arc	ܠܘܢܕܢܐ
ar	لندن
arz	لندن
ast	Londres
ay	London
az	London
bar	London
bat_smg	Londons
ba	Лондон
bcl	Londres
be_x_old	Лёндан
be	Горад Лондан
bg	Лондон
bh	लंदन
bi	London
bn	লন্ডন
bo	ལོན་ཏན་
br	Londrez
bs	London
bxr	Лондон
ca	Londres
cbk_zam	London
cdo	Lùng-dǔng
ceb	London
ce	Лондон
chr	ᏌᏉ ᏌᏉᏲᏳᏉᏉ
ckb	له‌ندەن
co	Londra
crh	London

Use Cases for the Wikidata Knowledge Graph

- **Build your applications using Wikidata**
 - Free corpus of structured knowledge
 - Easily accessible and standards-based
 - See <http://query.wikidata.org/>
- **Contextualize your enterprise data**
 - Wikidata provides stable identifiers into the open data world
 - Seamless integration of private data with open data
- **Enrich Wikidata with your data**
 - Contribute your data to Wikidata
 - Link to your own data, make it visible
 - Examples:
 - Open biomedical databases – Wikidata as a central hub
 - Cultural heritage



Histropedia

v1.7

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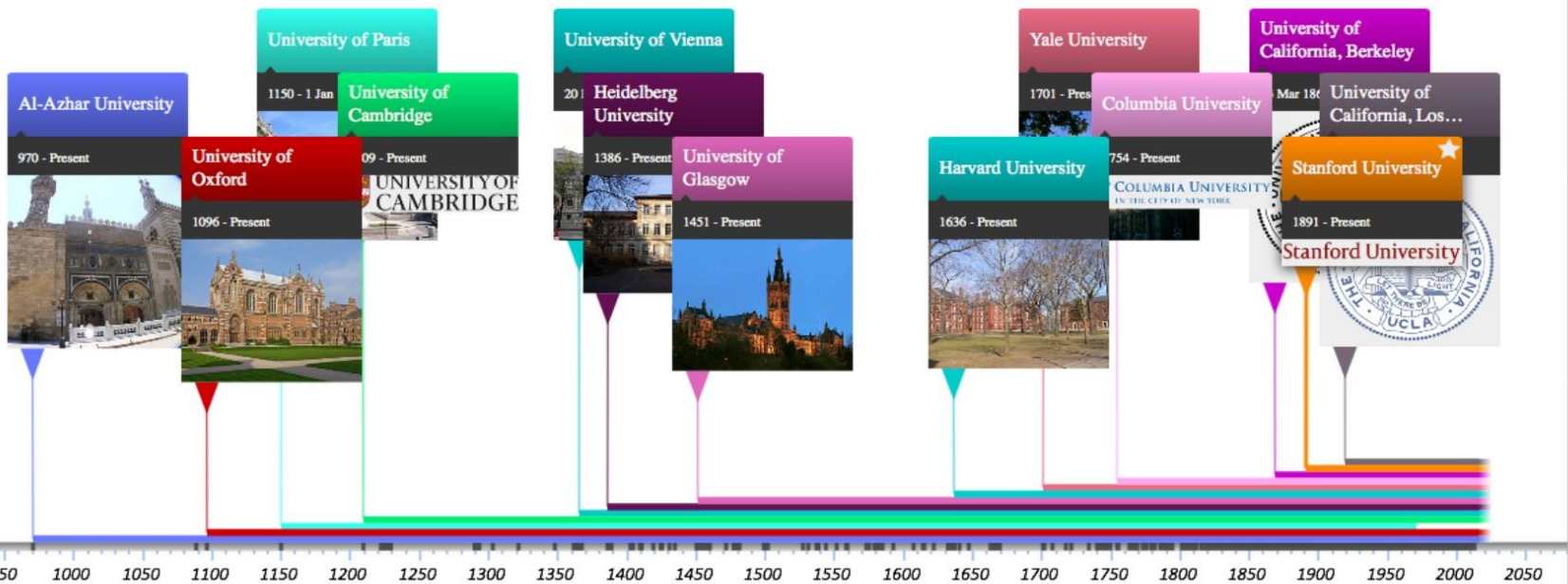
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Examples and Applications

Benefits of Knowledge Graphs

- Challenge:
 - Very context-rich data
 - Multi-disciplinary data, e.g. archaeologists, historians, librarians
 - Multi-institutional data
 - Complex domain, relationships, e.g. temporal, spatial, historical, political
- Benefits of Knowledge Graphs
 - Integration and interchange of heterogeneous cultural heritage information
 - Rich ontologies for knowledge representation
 - Deep semantics for true conceptual merging
 - Multi-lingual knowledge representation
 - Knowledge access across museums and organizations
 - Enabling knowledge sharing and collaboration

ResearchSpace: Knowledge Graphs for Cultural Heritage

- Collaboration environment for researchers in Cultural Heritage
 - Expert users: researchers, curators
- Based on CIDOC–CRM: very rich, expressive ontology
- Large, cross–museum data sets
 - E.g. British Museum: 100s millions of triples
- Advanced search capabilities
 - Supporting query construction
 - Sharing of searches, results, visualizations
- Knowledge sharing
 - Discussions around cultural heritage annotations
 - Argumentation support: Representation of conflicting views and opinions

<http://researchspace.org/>



The British
Museum



Demo ResearchSpace Platform

ResearchSpace Example Records ▾ Login ⓘ

Home

● Thing > refers to > 📍 Place > Vesuvius, Mount > remove

Found 120 matches

Grid Table Chart

● 👤 📍 ⌛ 📅 💬













▼ has material type (120) 💬

- onyx (1)
- opal (1)
- organic (3)
- ostrich eggshell (1)
- palm nut (1)
- palm stem (1)
- paper (120)
- pear wood (1)
- pearl (1)
- pearlshell (2)

▶ has technique type (120) 💬

▶ has type (120) 💬

Hide Filter

 <p>Montis Vesuvii fauces et ...</p>	 <p>View of Mount Vesuvius, ...</p>	 <p>Eruption of a volcano at n...</p>	 <p>View of the Bay of Naple...</p>
 <p>Eruption of Vesuvius, 8th ...</p>	 <p>Mount Vesuvius from San...</p>	 <p>Crater of Vesuvius, paper ...</p>	 <p>Eruption of the Soufrière ...</p>
			

Examples and Applications

Life Sciences

Benefits of Knowledge Graphs in the Life Sciences

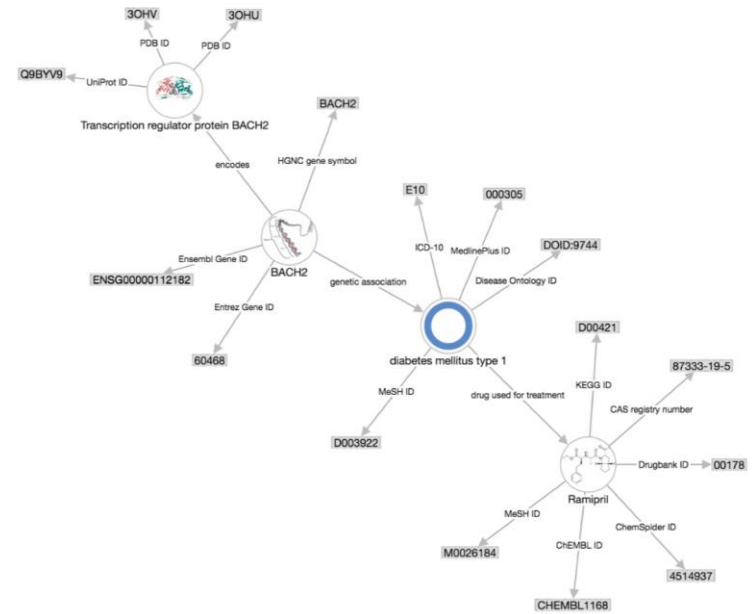
Challenge:

- Much of the relevant knowledge in external databases
- Many disparate databases / data silos
- Many different data formats
- Complex domain, complex relationships
e.g. *compounds, targets, pathways, diseases and tissues*



Benefits of Knowledge Graphs in the Life Sciences

- Integrated knowledge representation
 - Common format
- Integrated knowledge access:
One-stop portals



metaphacts sparql Account

Find: **Drugs MEDICAL CONDITION TREATED diabetes mellitus type 1**

Find: or and remove

medical condition treated (4)

- Acropustulosis (5)
- Alopecia areata (1)
- Atrial fibrillation (1)
- B-cell lymphoma (1)
- Behçet's disease (1)
- Crohn's disease (2)
- Early-onset Alzheimer's disease (3)
- Familial Mediterranean fever (2)
- Familial cold urticaria (1)

Filter Results

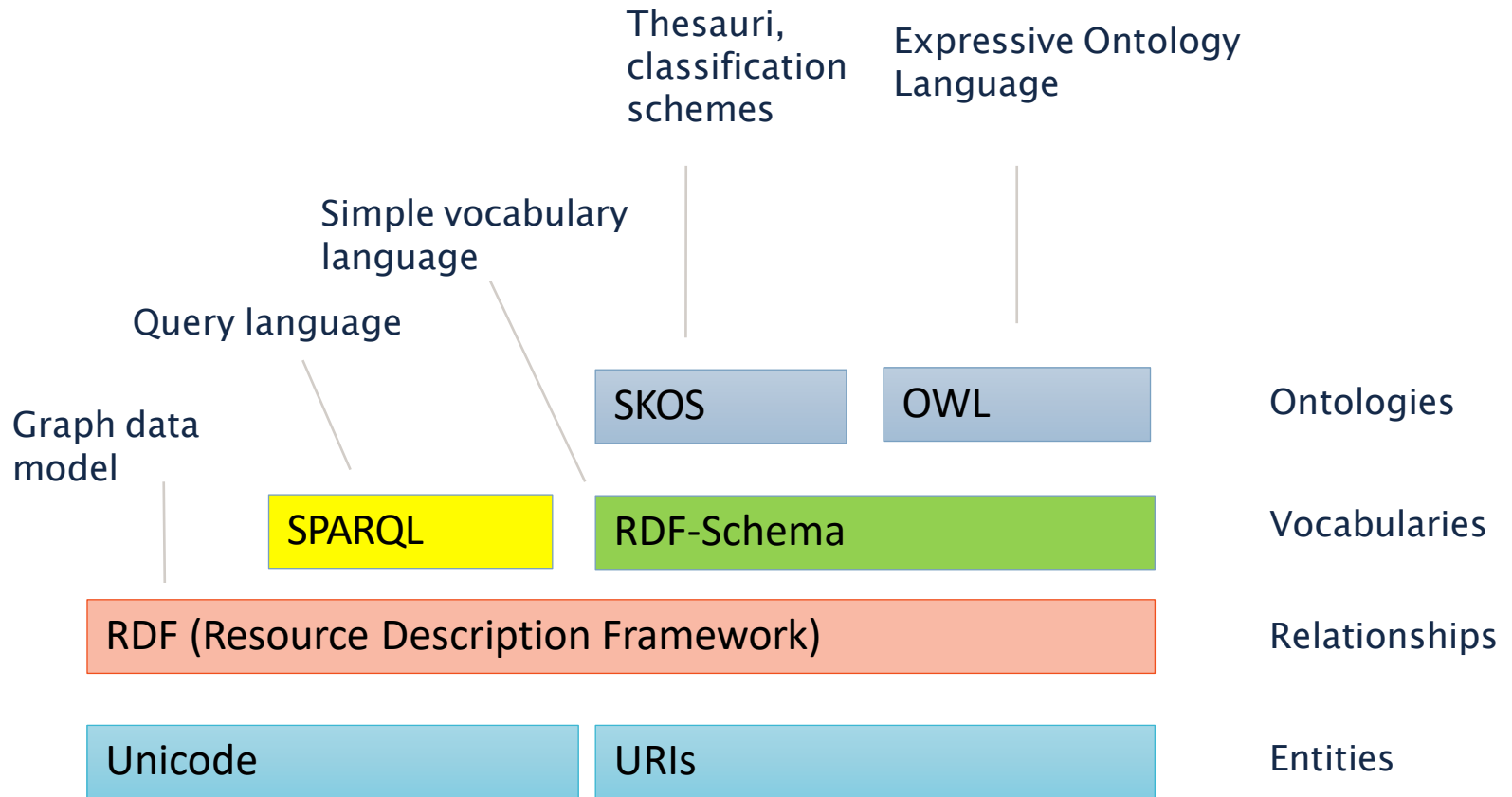
- Calcitriol
- Glyburide
- Ramipril
- Sirolimus

type (1)

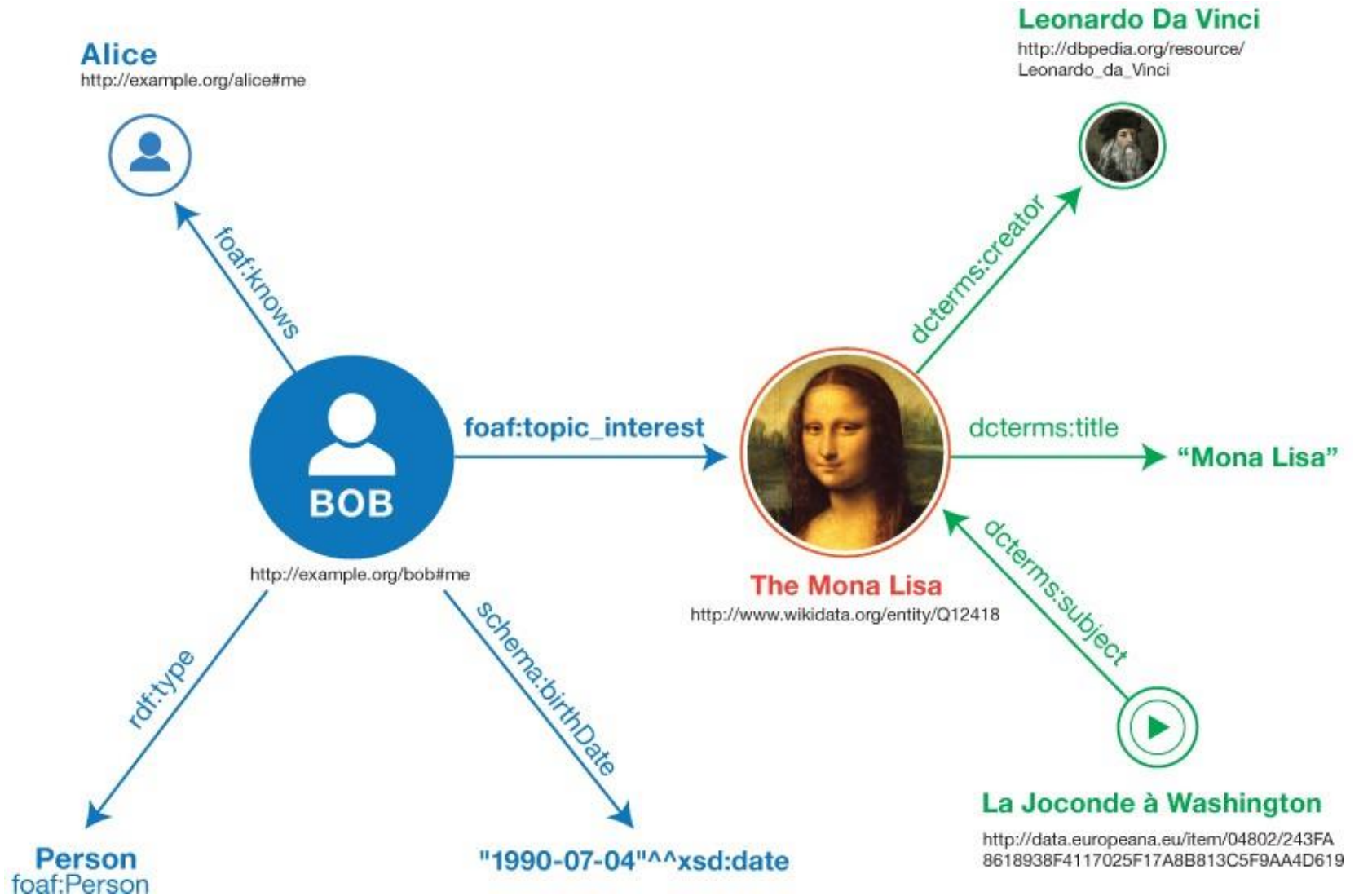
Save this Search Definition Save as New Set Add to Existing Set

Standards and Principles

Knowledge Graphs Built on the Semantic Web Layer Cake



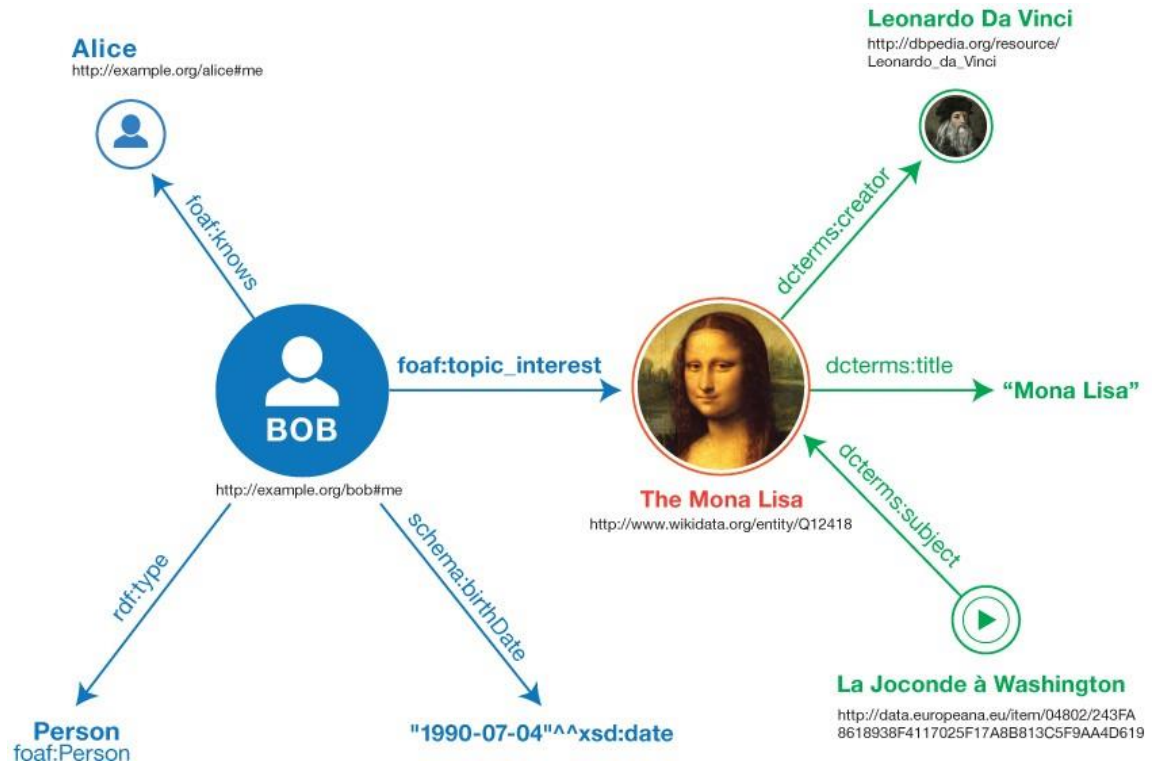
Our Knowledge Graph again (a bit more technical)



Our Knowledge Graph again (a bit more technical)

Graph consists of:

- Resources (identified via URIs)
- Literals: data values with data type (URI) or language (multilinguality integrated)
- Attributes of resources are also URI-identified (from *vocabularies*)
- Various data sources and vocabularies can be arbitrarily mixed and meshed
- URIs can be shortened with namespace prefixes; e.g. schema: → <http://schema.org/>



Allows one to talk about anything

Uniform Resource Identifier (URI) can be used to identify entities

http://dbpedia.org/resource/Leonardo_da_Vinci

is a name for Leonardo da Vinci

dbpedia:
Leonardo_da_Vinci

<http://www.wikidata.org/entity/Q12418>

is a name for the Mona Lisa painting

wd:Q12418

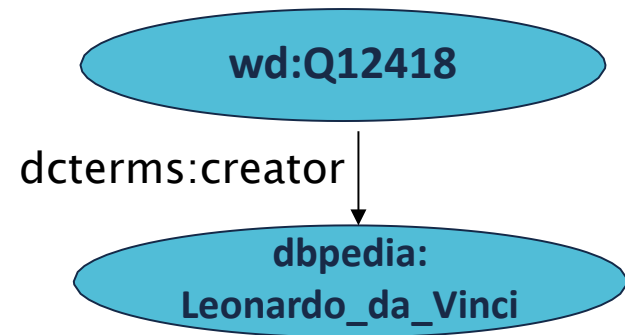
Allows one to express statements

An RDF statement consists of:

- Subject: resource identified by a URI
- Predicate: resource identified by a URI
- Object: resource or literal

Variety of RDF syntaxes,
e.g. Turtle (Terse RDF Triple Language):

```
wd:Q12418 dcterms:creator dbpedia:Leonardo_da_Vinci .
```



- Query language for RDF-based knowledge graphs.
- Designed to use a syntax similar to SQL for retrieving data from relational databases.
- Different query forms:
 - **SELECT** returns variables and their bindings directly.
 - **CONSTRUCT** returns a single RDF graph specified by a graph template.
 - **ASK** test whether or not a query pattern has a solution. Returns yes/no.
 - **DESCRIBE** returns a single RDF graph containing RDF data about resources.

Main idea: Pattern matching

- Queries describe sub-graphs of the queried graph
- **Graph** patterns are RDF graphs specified in Turtle syntax, which contain variables (prefixed by either “?” or “\$”)

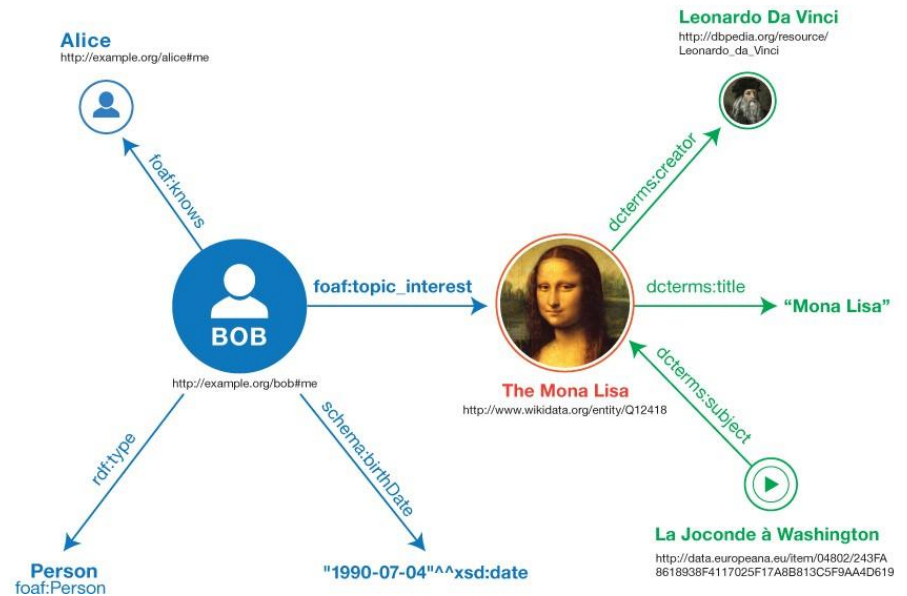


- Sub-graphs that match the graph patterns yield a **result**
- The syntax of a **SELECT** query is as follows:
 - **SELECT** nominates which components of the matches made against the data should be returned.
 - **FROM** (optional) indicates the sources for the data against which to find matches.
 - **WHERE** defines patterns to match against the data.
 - **ORDER BY** defines a means to order the selected matches.

SPARQL - * Protocol and RDF Query Language

Example:

Select the creator of the things that Bob is interested in.



PREFIX foaf: <http://xmlns.com/foaf/0.1/>

PREFIX dcterms: <http://purl.org/dc/terms/>

```
SELECT ?creator
```

```
WHERE {
```

```
  <http://example.org/bob#me> foaf:topic_interest ?interest .
```

```
  ?interest dcterms:creator ?creator
```

```
}
```

Results: [dbpedia:Leonardo_da_Vinci](http://dbpedia.org/resource/Leonardo_da_Vinci)