metaphacts

Smart Data. Smart Apps. Smart Decisions.

Getting Started with Knowledge Graphs

European Semantic Web Conference
May 29, 2017
Peter Haase

About the Speaker

metaphacts

Peter Haase

- Interest and experience in ontologies, semantic technologies and Linked Data
- PhD in KR and semantic technologies
- 15 years in academic research and software development
- Contributor to OWL 2 standard

metaphacts Company Facts

- Founded in Q4 2014
- Headquartered in Walldorf, Germany
- Currently ~10 people
- Platform for knowledge graph interaction & application development

Agenda

Introduction: What are Knowledge Graphs?

Examples and Applications

- Wikidata
- Cultural Heritage
- Industrial Applications

Standards and Principles

Knowledge Graph Management

Hands-on Exercises:

- metaphactory Knowledge Graph Platform

metaphacts

Smart Data. Smart Apps. Smart Decisions.

Preparation Hands-on Exercises

Hands-on Exercises

metaphacts

- Download metaphactory (or copy from USB stick)
  http://www.knowledgegraph.info/

- Follow README, start metaphactory
  start.sh / start.bat

- Open start page
  http://localhost:10214

- Follow “Getting started tutorial”
  http://localhost:10214/resource/Help:Tutorial

metaphacts

Smart Data. Smart Apps. Smart Decisions.

Introduction

What are Knowledge Graphs?

The Rise of Knowledge Graphs

metaphacts

WIKIDATA

Why (Knowledge) Graphs?

metaphacts

- 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

metaphacts

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

What are Knowledge Graphs?

metaphacts

- **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

metaphacts

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

metaphacts

Smart Data. Smart Apps. Smart Decisions.

Examples and Applications

Google Knowledge Graph

metaphacts

Google Knowledge Graph

metaphacts

Entity Search and Summarizations

Google

mona lisa

Sign in

All Images Videos News Maps More Search tools

About 21,500,000 results (1.11 seconds)

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 ...

Mona Lisa

Work of art

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 ...
Wikipedia

Artist: Leonardo da Vinci

Dimensions: 77 cm x 53 cm

Location: The Louvre (since 1797)

Created: 1503

Media: Oil paint

Periods: High Renaissance, Renaissance

Google Knowledge Graph

metaphacts

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 Knowledge Graph

metaphacts

Factual Answers

Google

when was leonardo da vinci born

Sign in

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

metaphacts

Google Search > Knowledge Graph Search API

Search

All Products

GUIDES REFERENCE

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.

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.)

Contents
Typical use cases
Sample request
Knowledge Graph entities

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

THE ECONOMIC GRAPH

metaphacts

Smart Data. Smart Apps. Smart Decisions.

Examples and Applications

Wikidata

Open Knowledge Graphs

metaphacts

Query the Knowledge of Wikipedia like a Database

metaphacts

Wikipedia page

Create account Log in

Article Talk Read View source View history Search

WIKIPEDIA
The Free Encyclopedia

Main page
Contents
Featured content
Current events
Random article
Donate to Wikipedia
Wikipedia store

Interaction
Help
About Wikipedia
Community portal
Recent changes
Contact page

Tools
What links here
Related changes
Upload file
Special pages
Permanent link
Page information
Wikidata item
Cite this page

Print/export
Create a book
Download as PDF
Printable version

Languages
Аҿсҭа
Адыгабзэ
Afrikaans

London

From Wikipedia, the free encyclopedia

Coordinates: 51°30′26″N 0°7′39″W

This article is about the capital city. For the region of England, see Greater London. For the historic city and financial district within London, see City of London. For other uses, see London (disambiguation).

London /ˈlʌndən/ is the capital and most populous city of England and the United Kingdom.[3][4] Standing on the River Thames, London has been a major settlement for two millennia, its history going back to its founding by the Romans, who named it *Londinium*.[5] London's ancient core, the City of London, largely retains its 1.12-square-mile (2.9 km²) medieval boundaries and in 2011 had a resident population of 7,375, making it the smallest city in England. Since at least the 19th century, the term *London* has also referred to the metropolis developed around this core.[6] The bulk of this conurbation forms Greater London,[7][8][note 1] a region of England governed by the Mayor of London and the London Assembly.[9][note 2] The conurbation also covers two English counties: the City of London and the county of Greater London.[10]

London is a leading global city,[11][12] with strengths in the arts, commerce, education, entertainment, fashion, finance, healthcare, media, professional services, research and development, tourism, and transport all contributing to its prominence.[13][14][15][16] It is one of the world's leading financial centres[17][18][19] and has the fifth-or sixth-largest metropolitan area GDP in the world depending on measurement.[note 3][20][21] London is a world cultural capital.[22][23][24][25] It is the world's most-visited city as measured by international arrivals[26] and has the world's largest city airport system measured by passenger traffic.[27] London's 43 universities form the largest concentration of higher education institutes in Europe.[28] In 2012, London became the first city to host the modern Summer Olympic Games three times.[29]

London has a diverse range of peoples and cultures, and more than 300 languages are spoken within Greater London.[30] The Greater London Authority estimated its population to be 8.63 million in 2015,[2] the largest of any municipality in the European Union,[31] and accounting for 12.5 percent of the UK population.[32] London's urban area is the second most populous in the EU, after Paris, with 9,787,426 inhabitants according to the 2011 census.[33] The city's metropolitan area is one of the most populous in Europe with 13,879,757 inhabitants,[note 4][34] while the Greater London Authority states the population of the *city-region* (covering a large part of south east England) as 22.7 million.[35] London was the world's most populous city from around 1831 to 1925.[36]

London

Central London skyline, Buckingham Palace, and Palace of Westminster

A query against Wikipedia

metaphacts sparql Login

Largest cities in the world with a female mayor

Filter Results

city	mayor	population
Madrid	Ana Botella	3165235
Paris	Anne Hidalgo	2240621
Houston	Annise Parker	2195914
Warsaw	Hanna Gronkiewicz-Waltz	1726581
Prague	Adriana Krnáčová	1243201
Valencia	Rita Barberá Nolla	792303
Taguig	Lani Cayetano	644473
Dresden	Helma Orosz	531982
Zürich	Corine Mauch	400028
Resistencia	Aída Beatríz Máxima Ayala	300000

21

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.**
  - 26 million entities
  - 150 million statements
  - 130 million labels
  - 350 languages
  - >1500 million triples

London (Q84)

capital city of England and the United Kingdom [edit]

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

In more languages

Statements

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

instance of	metropolitan area 0 references [add reference]	[edit]
	city with millions of inhabitants 1 reference	[edit]
	metropolis 0 references [add reference]	[edit]
	financial centre 0 references [add reference]	[edit]
	capital country: United Kingdom England 0 references [add reference]	[edit]
		[add]

Wikipedia (225 entries) [edit] [Collapse]

ab Лондан
ace London
af Londen
als London
am ለንደን
ang Lunden
an Londres
arc ܠܘܢܕܘܢ
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་དོན།
br Londrez
bs London
bxr Лондон
ca Londres
cbk_zam London
cdo Lùng-dŭng
ceb London
ce Лондон
chr ᏗᏫᎾᏂᏍᏓᏳᎯ
ckb لەندەن
co Londra
crh London

Leonardo da Vinci (Q762)

Italian Renaissance polymath

Leonardo | da Vinci | Leonardo de Vinza | Léonard | Lionardo | Leonardo d'Avinci | Леонардо | Leonardo da Vince | Liyūnārdū Dāvīnshī | Leonardo di Ser Piero da Vinci | Léonard de Vinci | Leonardo da Vinchi | Leonardo D'Vinci | Leonardo Da Vinci | Leonardo De Vinci | Léonardo de Vinci | da Vinci Leonardo | Leonard Davincy | Lieh-ao-na-to | Leonardo di ser Piero da Vinci

In more languages

Statements

instance of	human

2 references

imported from	English Wikipedia
stated in	artist list of the National Museum of Sweden
publication date	12 February 2016
retrieved	27 February 2016
reference URL	http://kulturnav.org/ba0098eb-25b5-4c6a-8af7-2d7d884bf1fc

image	Leonardo self.jpg

0 references

sex or gender	male

3 references

imported from	Virtual International Authority File
stated in	Integrated Authority File
retrieved	9 April 2014
stated in	artist list of the National Museum of Sweden
publication date	12 February 2016

Wikipedia (202 entries) [Collapse]

ab	Леонардо да Винчи
af	Leonardo da Vinci
als	Leonardo da Vinci
am	ሊዮናርዶ ዳቪንቺ
an	Leonardo da Vinci
arc	ܠܐܘܢܐܪܕܘ ܕܒܝܢܨܝ
ar	ليوناردو دا فينشي
arz	ليوناردو دافينشى
ast	Leonardo da Vinci
as	লিঅ'নাৰ্ডো দা ভিন্সি
ay	Leonardo da Vinci
azb	لئوناردو داوینچی
az	Leonardo da Vinçi
bar	Leonardo da Vinci
bat_smg	Leuonards da Vėnčės
ba	Леонардо да Винчи
bcl	Leonardo Da Vinci
be_x_old	Леанарда да Вінчы
be	Леанарда да Вінчы
bg	Леонардо да Винчи
bh	लियोनार्डो डा विंची
bi	Leonardo da Vinci
bn	লিওনার্দো দা ভিঞ্চি
bo	ལེཨོ་ན་ཌོ་ད་ཝིན་ཅི།
br	Leonardo da Vinci
bs	Leonardo da Vinci
bxr	Леонардо да Винчи
ca	Leonardo da Vinci
cbk_zam	Leonardo da Vinci
ceb	Leonardo da Vinci
ce	Леонардо да Винчи

Wikidata Query Service

https://query.wikidata.org

Wikidata Query | Examples | Prefixes | Tools | Help | English

```
#Paintings by Leonardo da Vinci
#defaultView:ImageGrid
SELECT *
WHERE
{
  ?item wdt:P31 wd:Q3305213 .
  ?item wdt:P170 wd:Q762 .
  ?item wdt:P18 ?pic .
}
```

Find instance of painting with creator Leonardo da Vinci

Show image

Limit

Press [CTRL-SPACE] to activate auto completion.

Data updated a few seconds ago

Run | Clear | 35 Results in 138 ms | Display | Download | Link

commons:Mona Lisa, by Leonardo da Vinci, from C2RMF retouched.jpg
wd:Q12418

commons:Lascapigliata.jpg
wd:Q797902

commons:Leonardo da Vinci attributed - Madonna Litta.jpg
wd:Q1327676

commons:La Battaglia di Anghiari di Leonardo.jpg
wd:Q2397593

commons:Leonardo Da Vinci - Vergine delle Rocce (Louvre).jpg
wd:Q11935346

Use Cases for the Wikidata Knowledge Graph

metaphacts

- **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

Inventory

add a book

friends & groups

browse books

exchanges

Dan Brown

American author

1964 -

country of citizenship: United States of America

native language: English

educated at: Amherst College

occupation: writer, novelist, teacher

Daniel "Dan" Brown (born June 22, 1964) is an American author of thriller fiction who is best known for the 2003

- The Da Vinci Code

The Da Vinci Code is a 2003 mystery-detective novel by Dan Brown. It follows symbologist Robert Langdon and cryptologist Sophie Neveu after a murder in the Louvre Museum in Paris, when they become involved in a ...

author: Dan Brown

2003

more details

add to my inventory

1 in your network

Angels & Demons

author: Dan Brown

more details

add to my inventory

0 in your network

Deception Point

Deception Point is a 2001 techno-thriller novel by Dan Brown.

author: Dan Brown

more details

add to my inventory

0 in your network

Ψηφιακό Οχυρό

Digital Fortress is a techno-thriller novel written by American author Dan Brown and published in 1998 by St. Martin's Press. ...

author: Dan Brown

more details

add to my inventory

0 in your network

The Lost Symbol

The Lost Symbol is a 2009 novel written by American writer Dan Brown. It is a thriller set in Washington, D.C., after the events of The Da Vinci Code, and relies on Freemasonry for both its recurring theme and its major characters,...

author: Dan Brown

more details

add to my inventory

0 in your network

Histropedia

metaphacts

v1.7 Follow us Timeline | About | Contact | How it works | Join Community Feedback

histropedia Top 20 Timelines Start searching for your topic... Compact Save Sign In

Al-Azhar University 970 - Present
University of Oxford 1096 - Present
University of Paris 1150 - 1 Jan
University of Cambridge 09 - Present
University of Vienna
Heidelberg University 1386 - Present
University of Glasgow 1451 - Present
Harvard University 1636 - Present
Yale University 1701 - Pres
Columbia University 754 - Present
University of California, Berkeley Mar 18
University of California, Los…
Stanford University 1891 - Present

850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050

Universities Share Timeline

Wikipedia Twitter Books TV & Film Music YouTube

metaphacts

Smart Data. Smart Apps. Smart Decisions.

Examples and Applications

Cultural Heritage

Benefits of Knowledge Graphs for Cultural Heritage

metaphacts

- 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

metaphacts

- 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 opionions

http://researchspace.org/

RESEARCH SPACE

The British Museum

CIDOC CRM

Demo ResearchSpace Platform

metaphacts

ResearchSpace

Example Records | Login

Home

Thing | refers to | Place | Vesuvius, Mount | remove

Found 120 matches

Grid | Table | Chart

Hide Filter

- 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)

Montis Vesuvii fauces et ...

View of Mount Vesuvius, ...

Eruption of a volcano at n...

View of the Bay of Naple...

Eruption of Vesuvius, 8th ...

Mount Vesuvius from San...

Crater of Vesuvius, paper ...

Eruption of the Soufrière ...

metaphacts

Smart Data. Smart Apps. Smart Decisions.

Standards and Principles

Holistic Knowledge

metaphacts

Multi-domain, source, granularity

- **Instance data** (ground truth)
- **Schema data** (vocabularies, ontologies)
- **Metadata** (e.g. provenance, versioning, documentation licensing)
- Comprehensive **taxonomies** to categorize entities
- **Links** between internal and external data
- **Mappings** to data stored in other systems and databases

Semantics on the Web

metaphacts

Digital signatures, recommendations

Application specific declarative-knowledge

Proof generation, exchange, validation

Query language

Expressive vocabulary (ontology) language

Simple vocabulary (schema) language

Basic data model

Syntactic basis

Semantic Web Stack
Berners-Lee (2006)

Knowledge Graphs Built on the Semantic Web Layer Cake

Our Knowledge Graph again (a bit more technical)

metaphacts

Our Knowledge Graph again (a bit more technical)

metaphacts

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/

metaphacts

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**

http://www.wikidata.org/entity/Q12418
is a name for the **Mona Lisa painting**

metaphacts

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

metaphacts

N-Triples Syntax

```
<http://www.wikidata.org/entity/Q12418>
<http://purl.org/dc/terms/creator>
<http://dbpedia.org/resource/Leonardo_da_Vinci> .

<http://www.wikidata.org/entity/Q12418>
<http://purl.org/dc/terms/title>
"Mona Lisa" .
```

URIs are given in angle brackets in N-Triples.

In N-Triples every statement is terminated with a full stop.

Literals are given in quotes in N-Triples.

RDF Graphs

- Every set of RDF assertions can then be drawn and manipulated as a (labelled directed) graph:
  - **Resources** – the subjects and objects are nodes of the graph.
  - **Predicates** – each predicate use becomes a label for an arc, connecting the subject to the object.

Resource Description Framework (RDF)

RDF Turtle

metaphacts

- Turtle is a syntax for RDF more readable.
- Since many URIs share same basis we use **prefixes**:

```
@prefix foaf: <http://xmlns.com/foaf/0.1/>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix schema: <http://schema.org/>.
@prefix dcterms: <http://purl.org/dc/terms/>.
@prefix wd: <http://www.wikidata.org/entity/>.
```

RDF Turtle

- Also has a simple *shorthand* for class membership:

```
@prefix foaf: <http://xmlns.com/foaf/0.1/>.
<http://example.org/bob#me> a foaf:Person .
```

Is **equivalent** to:

```
<http://example.org/bob#me>
<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
<http://xmlns.com/foaf/0.1/Person>.
```

RDF Turtle

- When multiple statements apply to **same subject** they can be abbreviated as follows:

```
wd:Q12418 dcterms:title "Mona Lisa" ;
          dcterms:creator <http://dbpedia.org/resource/Leonardo_da_Vinci> .
```

Same subject

Hands-on: Loading Data

1. Follow http://localhost:10214/resource/Help:Tutorial

2. Load sample.ttl via http://localhost:10214/resource/Admin:DataImportExport

3. Browse and explore sample data

Describing Data: Vocabularies

metaphacts

- Collections of defined **relationships** and **classes** of resources.
  - Classes group together similar resources.
- Terms from well-known vocabularies should be **reused** wherever possible.
- New terms should be defined only if you can not find required terms in existing vocabularies.

Describing Data: Vocabularies

metaphacts

A set of well-known vocabularies has evolved in the Semantic Web community. **Some** of them are:

Vocabulary	Description	Classes and Relationships
Friend-of-a-Friend **(FOAF)**	Vocabulary for describing people.	foaf:Person, foaf:Agent, foaf:name, foaf:knows, foaf:member
Dublin Core **(DC)**	Defines general metadata attributes.	dc:FileFormat, dc:MediaType, dc:creator, dc:description
Organization Ontology **(org)**	Publishing of organization information.	org:Organisation, org:Site, org:Role, org:member, org:hasSite
schema.org	Cross-domain vocabulary for annotation of Web pages.	schema:Event, schema:Product, schema:location, schema:image

RDF-S – RDF Schema

metaphacts

- Language for two tasks w.r.t. the RDF data model:
  - Definition of vocabulary – nominate:
    - the ‘types’, i.e., classes, of things we might make assertions about, and
    - the properties we might apply, as predicates in these assertions, to capture their relationships.
  - Inference – given a set of assertions, using these classes and properties, specify what should be inferred about assertions that are implicitly made.

RDF-S – RDF Schema

metaphacts

- **rdfs:Class** – Example:

  `foaf:Person – Represents the class of persons`

- **rdf:Property** – Class of RDF properties. Example:

  `foaf:knows – Represents that a person "knows" another`

- **rdfs:domain** – States that any resource that has a given property is an instance of one or more classes

  `foaf:knows rdfs:domain foaf:Person`

- **rdfs:range** – States that the values of a property are instances of one or more classes

  `foaf:knows rdfs:range foaf:Person`

RDF-S – RDF Schema

metaphacts

Schema

```
foaf:knows
rdfs:range
foaf:Person .
```

Existing fact

```
<http://example.org/bob#me>
foaf:knows
<http://example.org/alice#me>.
```

Inferred fact

```
<http://example.org/alice#me>
rdf:type
foaf:Person.
```

We *expect* to use this vocabulary to make assertions about persons.

Having made such an assertion...

Inferences can be drawn that we did not explicitly make

Hands-on: Load FOAF Vocabulary

1. Load foaf.rdf via http://localhost:10214/resource/Admin:DataImportExport

2. Browse and explore FOAF vocabulary

OWL – Web Ontology Language

metaphacts

- RDFS provides a simplified ontological language for defining vocabularies about specific domains.
- **OWL** provides more ontological constructs for knowledge representation.
- Semantics grounded in **Description Logics**.
- Most graph databases concentrate on the use of RDFS with a subset of OWL features.

OWL 2.0 – Web Ontology Language 2.0

metaphacts

Extends the DL further, but has three more computable fragments (profiles).

OWL 2 Full

- Used informally to refer to RDF graphs considered as OWL 2 ontologies and interpreted using the RDF-Based Semantics.

OWL 2 DL

- Used informally to refer to OWL 2 DL ontologies interpreted using the Direct Semantics.

OWL 2 EL

- Limited to basic classification, but with polynomial-time reasoning.

OWL 2 QL

- Designed to be translatable to relational database querying.

OWL 2 RL

- Designed to be efficiently implementable in rule-based systems.

55

OWL – Web Ontology Language

metaphacts

OWL is made up of **terms** which provide for:

- **Class construction**: forming new classes from membership of existing ones (e.g., unionOf, intersectionOf, etc.).
- **Property construction**: distinction between OWL ObjectProperties (resources as values) and OWL DatatypeProperties (literals as values).
- **Class axioms**: sub-class, equivalence and disjointness relationships.
- **Property axioms**: sub-property relationship, equivalence and disjointness, and relationships between properties.
- **Individual axioms**: statements about individuals (sameIndividual, differentIndividuals).

Example: CIDOC-CRM Ontology

Class: Physical Thing
  SubClassOf: Legal Object
  SubClassOf: Spacetime Volume
  DisjointWith: Conceptual Object
  SubClassOf: consists_of some Material

Class: Person
  SubClassOf: Actor
  SubClassOf: Biological Object
  SubClassOf: was_born exactly 1
  SubClassOf: has_parent min 2

Hands-on: Load CIDOC-CRM Ontology

metaphacts

1. Load ecrm_current.owl via http://localhost:10214/resource/Admin:DataImportExport

2. Browse and explore CIDOC-CRM ontology

SKOS - Simple Knowledge Organization System

metaphacts

- Data model for knowledge organization systems (thesauri, classification scheme, taxonomies)

- Conceptual resources (concepts) can be
  - identified with URIs,
  - labeled with lexical strings in natural language,
  - documented with various types of note,
  - semantically related to each other in informal hierarchies and association networks and
  - aggregated into concept schemes.

http://www.w3.org/TR/skos-reference/

Example: Concept Definition for Paper

SPARQL – * Protocol and RDF Query Language

metaphacts

- 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.

metaphacts

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**

SPARQL – * Protocol and RDF Query Language

metaphacts

Data graph:

Graph pattern:

Results:

?interest
wd:Q12418

SPARQL – * Protocol and RDF Query Language

Data graph:

Graph pattern:

Results:

?interest	?creator
wd:Q12418	dbpedia: Leonardo_da_Vinci

SPARQL Query: Components

```
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
}
```

Prologue:

- Prefix definitions
- Subtly different from Turtle syntax - the final period is not used

SPARQL Query: Components

```
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
}
```

Query form:

- ASK, SELECT, DESCRIBE or CONSTRUCT
- SELECT retrieves variables and their bindings as a table

SPARQL Query: Components

```
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
}
```

Query pattern:

- Defines patterns to match against the data
- Generalises Turtle with variables and keywords – N.B. final period optional

Hands-on: Execute SPARQL Query

metaphacts

- Use the local SPARQL endpoint: http://localhost:10214/sparql

- Execute the queries from the tutorial

1. *Select all statements about Bob*
2. *Select the creator of the things that Bob is interested in.*

Query Form: ASK

metaphacts

- Namespaces are added with the 'PREFIX' directive
- Statement patterns that make up the graph are specified between brackets ("{}")

Query: Does Bob know Alice?

```
PREFIX foaf: http://xmlns.com/foaf/0.1/
ASK WHERE {
<http://example.org/bob#me> foaf:knows
<http://example.org/alice#me> }
```

Results:

true

Query: Is Alice interested in the Mona Lisa?

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX wd: <http://www.wikidata.org/entity/>
ASK WHERE {
<http://example.org/alice#me> foaf:topic_interest
wd:Q12418}
```

Results:

false

Query Form: SELECT – Property Paths

metaphacts

- A property path is a possible route through a graph between two graph nodes
- Property paths allow for more concise expression of some SPARQL basic graph patterns and also add the ability to match arbitrary length paths

Query: *Creator of 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 / dcterms:creator ?creator
}
```

metaphacts

Filter expressions

- Different types of filters and functions may be used

Filter: Comparison and logical operators

Query: *People who know someone who does not know them?*

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dcterms: <http://purl.org/dc/terms/>

SELECT ?person ?another WHERE {
  ?person foaf:knows ?another
  FILTER NOT EXISTS { ?another foaf:knows ?person }
}
```

Query Form: SELECT - Aggregates

metaphacts

- Calculate aggregate values: `COUNT`, `SUM`, `MIN`, `MAX`, `AVG`, `GROUP_CONCAT` and `SAMPLE`
- Built around the GROUP BY operator
- Prune at group level (cf. FILTER) using HAVING

Query: *How many friends do people have?*

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

SELECT ?person (COUNT(?another) as ?num_friends) WHERE {

  ?person a foaf:Person
  OPTIONAL { ?person foaf:knows ?another }

}
GROUP BY ?person
```

Query Form: CONSTRUCT

metaphacts

- **CONSTRUCT WHERE:** In order to query for a subgraph, without change, it is no longer necessary to repeat the graph pattern in the template

Example:

```
CONSTRUCT
WHERE {
  <http://example.org/bob#me> ?p ?o
}
```

Query Form: CONSTRUCT

metaphacts

- **Graph- and vocabulary transformations**

Example:

```
PREFIX wdt: <http://www.wikidata.org/prop/direct/>
PREFIX dcterms: <http://purl.org/dc/terms/>

CONSTRUCT { ?creator wdt:P800 ?work }
          # wdt:P800 = notable work
WHERE {
?work dcterms:creator ?creator
}
```

SPARQL Federated Query

metaphacts

- Allows federating across multiple SPARQL endpoints
- The SERVICE keyword instructs to invoke a portion of a SPARQL query against a remote SPARQL endpoint

Query: *Find information about things that Bob likes at Wikidata*

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dcterms: <http://purl.org/dc/terms/>

SELECT * WHERE {
<http://example.org/bob#me> foaf:topic_interest ?interest .
SERVICE <https://query.wikidata.org/sparql> {
   ?interest ?predicate ?object }
}
```

SPARQL 1.1 Update

metaphacts

SPARQL 1.1 provides data update operations:

- **INSERT data:** adds some triples, given inline in the request, into a graph
- **DELETE data:** removes some triples, given inline in the request, if the respective graphs contains those
- **DELETE/INSERT data:** uses in parallel INSERT and DELETE

SPARQL Update: Example

```
BASE <http://example.org/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX wd: <http://www.wikidata.org/entity/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

WITH <http://www.metaphacts.com/tutorial/>
INSERT {
    <peter#me>      a foaf:Person ;
                    rdfs:label "Peter";
                    foaf:knows <alice#me> , <bob#me> ;
                    foaf:topic_interest wd:Q12418
}
WHERE {}
```

metaphacts

Smart Data. Smart Apps. Smart Decisions.

Knowledge Graph Management

Aspects of Knowledge Graph Management

metaphacts

KNOWLEDGE GRAPH STORAGE

- Scalable data loading and storage
- Querying and analytics
- Built-in inferencing and custom services
- Management of hybrid data sources

KNOWLEDGE GRAPH CREATION

- Model- and ontology development
- Semi-automatic creation from structures sources (data lifting)
- Interlinking of data from heterogeneous sources
- Collaborative authoring
- Data annotation
- Versioning and provenance
- Quality Assurance

KNOWLEDGE GRAPH CONSUMPTION

- Development of end-user oriented applications
- Interactive visualization
- Exploration
- Semantic search
- Natural language interfaces

metaphacts Supports the Whole Data Lifecyle

metaphacts

metaphactory as an Open Platform

metaphacts

BUILT IN OPEN SOURCE

- ✓ Dual licensing (LGPL & commercial license)
- ✓ Open Platform API and SDK
- ✓ Integration of external tools and application via APIs
- ✓ Easy development of own web components and services
- ✓ Full HTML5 compliance
- ✓ Re-usable, declaratively configurable Web Components

= Easy modification, customization, and extensibility

BUILT ON OPEN STANDARDS

- ✓ W3C Web Components
- ✓ W3C Open Annotation Data Model
- ✓ W3C Linked Data Platform Containers
- ✓ Data processing based on W3C standards such as RDF, SPARQL
- ✓ Expressive ontologies for schema modeling based on OWL 2, SKOS
- ✓ Rules, constraints, and query specification based on SPIN and RDF Data Shapes

= Sustainable Solution

metaphactory Platform Architecture

metaphacts

Applications

Expert/domain Users

Knowledge Graph Management

Developers

App Factory

End Users

Smart Apps

Services

Configuration

Catalog Services

Exploration

Visualization

Search

Access Control

Data

SPARQL Endpoint

Inferencing

Graph Database

Graph Analytics

Provenance

Users and their Benefits

metaphacts

EXPERT USERS

- Collaboratively construct and manage knowledge graphs
- Integrate data from heterogeneous sources
- Use standard connectors for a variety of data formats
- Benefit from scalable data processing for big graphs
- Conduct high-performance querying and analytics

DEVELOPERS

- Rapidly develop Web and mobile end-user oriented applications
- Benefit from various deployment modes: stand-alone, HA, scale-up, scale-out
- Interact with an easy-to-use interface
- Collaboratively manage, annotate and author data
- Use large set of custom query and templates catalogs
- Capture of provenance information

END USERS

- Benefit from user-friendly interaction with data
- Gain insights into complex relationships
- Enable transparency and extract value
- Ask questions and obtain precise results
- Reduce effort for data analysis
- Reduce noise – obtain targeted, high quality results
- Enhance quality of business decisions

Search

metaphacts

- Domain independent, fully customizable search widget
- Satisfy complex information needs without learning SPARQL
- Search functionalities
    - Graphical query construction
    - End user friendly search interfaces for building and sharing complex queries
    - Semantic auto suggestion
    - Interactive result visualization
    - Faceted search and exploration of item collections
- Ability to invoke external full text search indices such as Solr including the possibility to score, rank and limit the results for responsive autosuggestion
- Saving and sharing of queries and search results

Visualization

metaphacts

Carousel

Animated browsing through a list of result items

Graph

Visualize and explore connections in a graph view

Custom styling of the graph

Variety of graph layouts

Map

Displaying spatial data on a geographic map

Tree Table

Tree-based visualization, navigation and browsing through sub-tree structures

Chart

Visualize trends and relationships between numbers, ratios, or proportions

Table

Transform your queries into durable, interactive tables

Many customization possibilities, e.g. pagination, filters and cell templates

Authoring

metaphacts

- Annotations
  - Based on W3C Open Annotation Data Model
  - Automated semantic link extraction
- Form based authoring
  - Manually author and update instance data, backed by query templates, data dependencies, and type constraints
  - Rich editing components for special data types
  - Customizable flexible forms
  - Autosuggestion and validation against the knowledge graph
- Capturing of provenance information
- User group management

Install & Go: Out-of-the-Box Functionality

metaphacts

Get started

Getting Started Tutorial
to guide you through your first steps with metaphactory

Search

Keyword Search Interface
with semantic autosuggestion, driven by SPARQL

Management of Queries in Catalog
for easy reuse and updating

Explore

Data Overview Pages
with Web components for end-user friendly data presentation and interaction

Template-based Data Browser
used to define generic views which are automatically applied to entire sets of instances

Declarative Components

metaphacts

Example: Simple Semantic Search

Keyword search with semantic autosuggestion, driven by SPARQL

Set up in ~2 minutes!

1

Developer embeds 'semantic-simple-search' into the page

```
<semantic-simple-search data-
config='{
 "query":"
   SELECT ?result ?label ?desc
?img WHERE {
     ?result rdfs:label ?label .
     ?result rdfs:comment ?desc .
     ?result foaf:thumbnail ?img .
     FILTER(CONTAINS(?label,
?token))
 }",
 "searchTermVariable":"token", //
user input
 "template":"
   <span title="{{result}}">
     <img src="{{img}}"
height="30"/>
     {{label}} ({{desc}})</span>"
}'/>
```

2

Rendered component is displayed to the user and can be used right away

Search for something

3

Autosuggestions are dynamically computed based on query and user input

Amazonas

Amazonas (longest river in South America)

Amazon.com (American electronic commerce and cloud computing company)

HTML5 Template Pages

- Associate a class in the knowledge graph with a template
- The template is applied to instances of the class

metaphacts

Smart Data. Smart Apps. Smart Decisions.

Hands-on Exercises

Hands-on Exercises

metaphacts

DATA LOADING & QUERYING

- Loading your data
- Querying your data

VISUALIZATION

- Visualizing results in a table
- Visualizing results in a graph

SEARCH

- Embedding a simple search interface

AUTHORING

- Creating a template
- Inserting and updating data

Data Loading & Querying

metaphacts

1

Load data into the store via the data import and export administration page

2

Query the data via the SPARQL endpoint.

E.g.: issue a query for all statements made about Bob as a subject

3

Visualize results in a table

predicate	object
http://schema.org/birthDate	1990-07-04
http://schema.org/thumbnail	https://upload.wikimedia.org/wikipedia/commons/thumb/1/12/User_icon_2.svg/200px-User_icon_2.svg.png
http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://xmlns.com/foaf/0.1/Person
http://www.w3.org/2000/01/rdf-schema#label	Bob
http://xmlns.com/foaf/0.1/knows	http://example.org/alice#me
http://xmlns.com/foaf/0.1/topic_interest	http://www.wikidata.org/entity/Q12418

… or as raw data

Visualizing Results in a Table

metaphacts

1

Embed 'semantic-table' component

```
<semantic-table config='{
   "query":"SELECT * WHERE {
<http://example.org/bob#me>
?predicate ?object }"
    }'>
</semantic-table>
```

to visualize previous query as a table in a page

2

Customize the query to embed thumbnail images in the result visualization

```
SELECT ?uri ?label
?thumbnail WHERE { ?uri
rdfs:label ?label;
<http://schema.org/thumbnail
> ?thumbnail }
```

Use tupleTemplate to define a template for displaying the new table

3

Visualize results in a table displaying thumbnails as images, the labels of the resources as captions, and links to the individual resource pages

Visualizing Results in a Graph

metaphacts

1

Embed 'semantic-graph' component

```
<semantic-graph

query="CONSTRUCT WHERE { ?s ?p ?o
}">

</semantic-graph>
```

2

Visualize results in a graph

Embedding a Simple Search Interface

metaphacts

1

Embed 'semantic-simple-search' into the page

```
<semantic-simple-search
config='{
        "query":"
          SELECT ?uri ?label
WHERE {
            FILTER REGEX(?label,
\"?token\", \"i\")
            ?uri rdfs:label
?label
          } LIMIT 10
        ",

"searchTermVariable":"token",
        "resourceSelection":{

"resourceBindingName":"uri",
          "template":"<span
style=\"color: blue;\"
title=\"{{uri.value}}\">{{label.
value}}</span>"
        },

"inputPlaceholder":"Search for
something e.g. \"Bob\""
      }'>
 </semantic-simple-search>
```

2

Rendered component is displayed and can be used right away

Search for something e.g. "Bob"

3

Autosuggestions are dynamically computed based on query and user input

bob

Bob

Creating a Template

metaphacts

1

Use the templating mechanism to create a template for the resource type 'Person', to display:

- the person's name
- an image, if available
- his interests
- his friendship relationship

2

Visualize the result on Bob's instance page

Inserting and Updating Data

metaphacts

1

Use a SPARQL UPDATE operation against the SPARQL endpoint to create and add new instance data

- the person's name
- an image, if available
- his interests
- his friendship relationship

2

Visualize the result

Summary

metaphacts

- **Knowledge graphs** as a flexible model for data integration and knowledge representation
- Standards for **"semantic" knowledge graphs**
  - RDF as graph-based data model
  - OWL as expressive ontology language
  - SKOS for taxonomic knowledge
  - SPARQL as query language
- **Application areas**
  - Open knowledge graphs, e.g. Wikidata
  - Cultural Heritage
  - Life Sciences
  - And many more
- Get started with the metaphactory Knowledge Graph platform today!

Acknowledgements and Thanks

- Some slides build on the Euclid training material

  http://www.euclid-project.eu

- Thanks to the team at metaphacts

- Thanks to the ESWC organizers

metaphacts

metaphacts GmbH

Daimlerstraße 36

69190 Walldorf

Germany

p +49 6227 6989965

m +49 157 50152441

e info@metaphacts.com

@metaphacts

www.metaphacts.com