TECHNISCHE UNIVERSITÄT DRESDEN

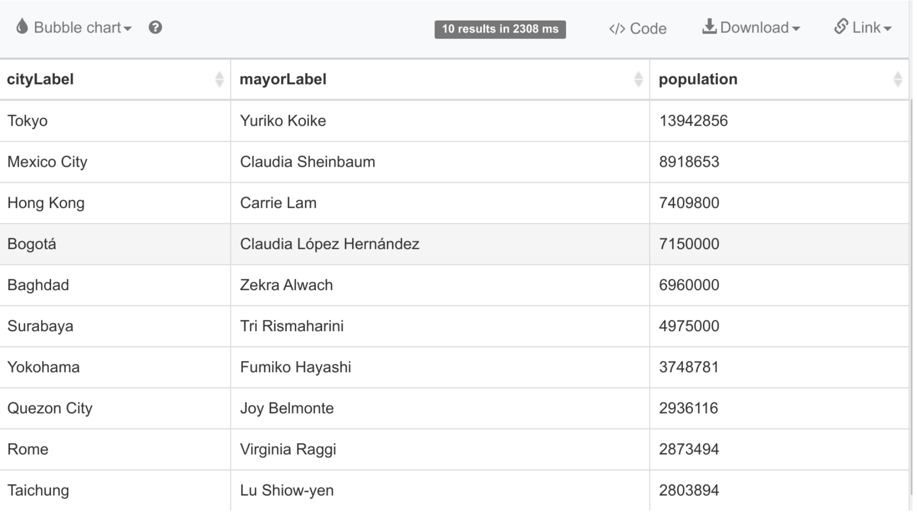
KNOWLEDGE GRAPHS

Lecture 4: Wikidata

Markus Krötzsch
Knowledge-Based Systems

TU Dresden, 5th Nov 2019

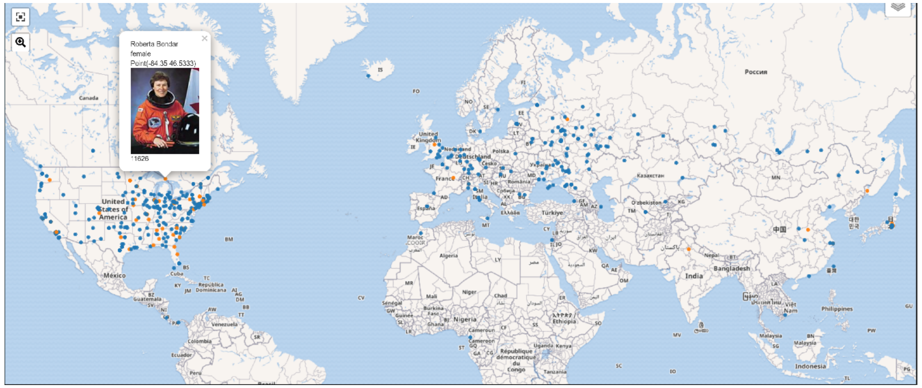
What are the ten largest cities with a female mayor?



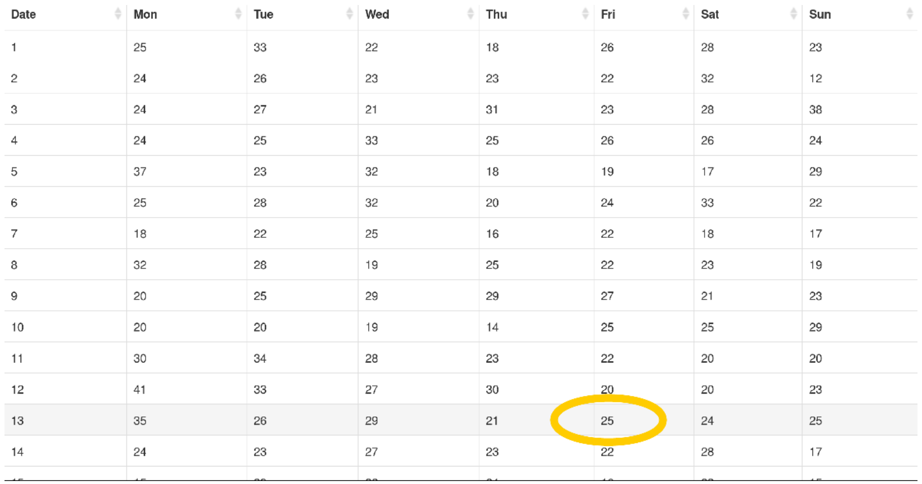
cityLabel	mayorLabel	population
Tokyo	Yuriko Koike	13942856
Mexico City	Claudia Sheinbaum	8918653
Hong Kong	Carrie Lam	7409800
Bogotá	Claudia López Hernández	7150000
Baghdad	Zekra Alwach	6960000
Surabaya	Tri Rismaharini	4975000
Yokohama	Fumiko Hayashi	3748781
Quezon City	Joy Belmonte	2936116
Rome	Virginia Raggi	2873494
Taichung	Lu Shiow-yen	2803894

Where are people born who travel to space?

(colour-coded by gender)

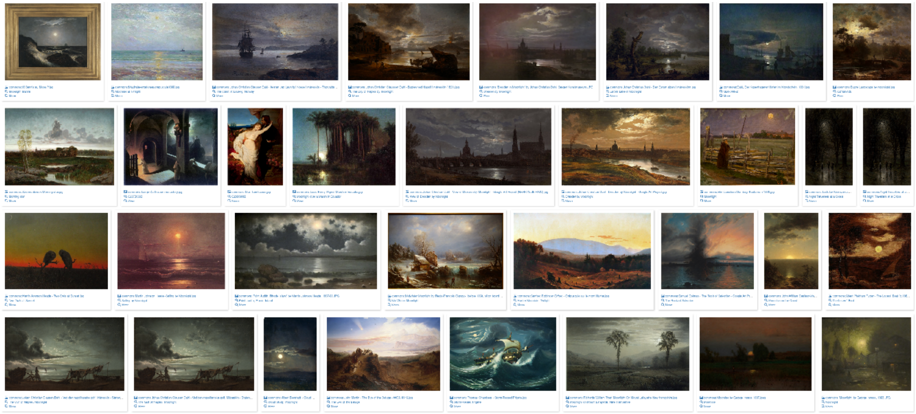


Which days of the week do disasters occur?

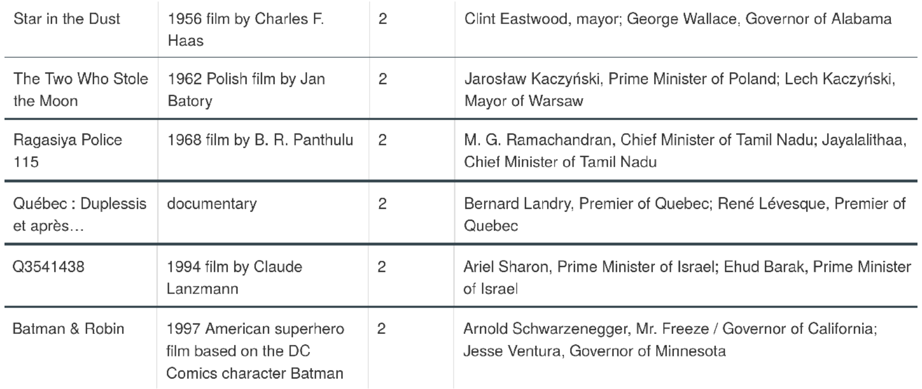


Date	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	25	33	22	18	26	28	23
2	24	26	23	23	22	32	12
3	24	27	21	31	23	28	38
4	24	25	33	25	26	26	24
5	37	23	32	18	19	17	29
6	25	28	32	20	24	33	22
7	18	22	25	16	22	18	17
8	32	28	19	25	22	23	19
9	20	25	29	29	27	21	23
10	20	20	19	14	25	25	29
11	30	34	28	23	22	20	20
12	41	33	27	30	20	20	23
13	35	26	29	21	25	24	25
14	24	23	27	23	22	28	17

Which 19th century paintings show the moon?



Which films co-star more than one future head of government?



Star in the Dust	1956 film by Charles F. Haas	2	Clint Eastwood, mayor; George Wallace, Governor of Alabama
The Two Who Stole the Moon	1962 Polish film by Jan Batory	2	Jarosław Kaczyński, Prime Minister of Poland; Lech Kaczyński, Mayor of Warsaw
Ragasiya Police 115	1968 film by B. R. Panthulu	2	M. G. Ramachandran, Chief Minister of Tamil Nadu; Jayalalithaa, Chief Minister of Tamil Nadu
Québec : Duplessis et après…	documentary	2	Bernard Landry, Premier of Quebec; René Lévesque, Premier of Quebec
Q3541438	1994 film by Claude Lanzmann	2	Ariel Sharon, Prime Minister of Israel; Ehud Barak, Prime Minister of Israel
Batman & Robin	1997 American superhero film based on the DC Comics character Batman	2	Arnold Schwarzenegger, Mr. Freeze / Governor of California; Jesse Ventura, Governor of Minnesota

A Free Knowledge Graph

Wikidata

- Wikipedia's knowledge graph
- Free, community-built database
- Large graph
  (October 2019: >800M statements on >65M entities)
- Large, active community
  (several 100K logged-in human editors)
- Many applications

Freely available, relevant, and active knowledge graph

A short history of Wikidata

Prehistory

- August 2005: Presentation “Wikipedia and the Semantic Web – The Missing Links” at the 1st Wikimedia Conference “Wikimania”, Frankfurt
- September 2005: First release of Semantic MediaWiki software, which since became an active stand-alone software project
- 2006–2011: Many talks and discussions at Wikimanias in Boston, Taipei, Alexandria, Buenos Aires, Gdańsk, and Haifa
- 2011/2012: WMF support and donations for starting Wikidata development are secured
- 1st April 2012: Wikidata development kick-off in Berlin

A short history of Wikidata

History

- 29th October 2012: wikidata.org is launched
- 15th Dec 2012: Item with ID number 1000000 created
- 4th Feb 2013: The first statements can be created
- Early 2013: Most Wikipedia language links relocate to Wikidata
- Late 2013: More than 100,000,000 edits on over 15M items
- Dec 2014: Google announces the closure of Freebase and migration to Wikidata
- 2014-2018: A total of >700M edits produce >55M items and >570M statements
- May 2018: Wikidata starts storing data about lexemes (=expressions in a language)
- Oct 2018: Senses of lexemes become supported
- across 2019: first Wikidata-like features become available on Wikimedia Commons

Many applications (1)

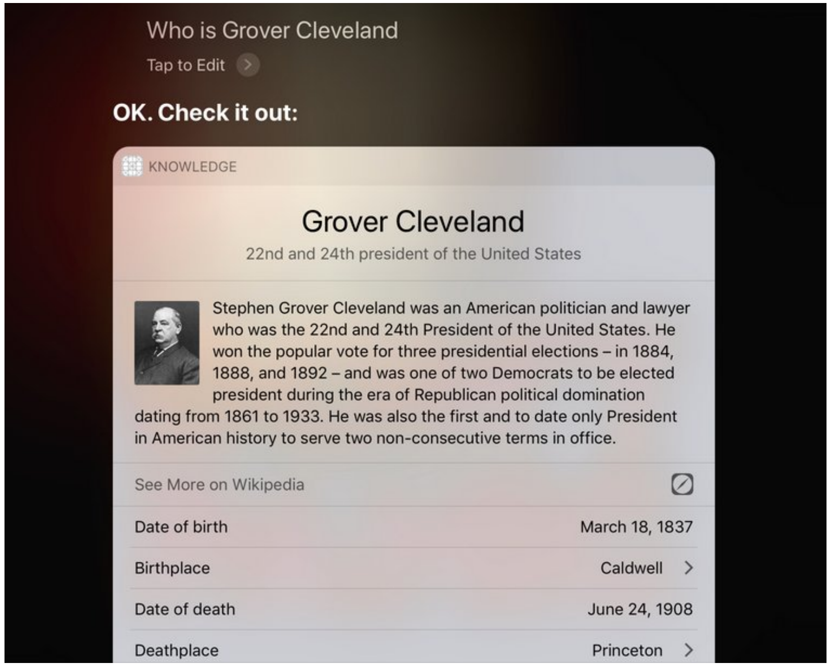
As of today, Wikidata content has been used in many ways.

Wikipedia & the Wikimedia community:

- Wikipedia inter-language links (see any Wikipedia page)
- Data displays in pages (auto-generated info boxes, article placeholders, result tables, . . .)
- Quality checks & edit-a-thons

External re-uses of data:

- Application-specific data-excerpts (e.g., Eurowings in-flight app)
- Data integration and quality control (e.g., Google checks own KG against Wikidata)
- Authority control & identity provider (VIAF, Open Streetmaps, DBLP, . . . link their content to Wikidata)
- Data-driven journalism (individual analyses as well as data-driven information portals)



Who is Grover Cleveland

Tap to Edit

OK. Check it out:

KNOWLEDGE

Grover Cleveland

22nd and 24th president of the United States

Stephen Grover Cleveland was an American politician and lawyer who was the 22nd and 24th President of the United States. He won the popular vote for three presidential elections – in 1884, 1888, and 1892 – and was one of two Democrats to be elected president during the era of Republican political domination dating from 1861 to 1933. He was also the first and to date only President in American history to serve two non-consecutive terms in office.

See More on Wikipedia

Date of birth	March 18, 1837
Birthplace	Caldwell
Date of death	June 24, 1908
Deathplace	Princeton

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- Data-driven journalism (individual analyses as well as data-driven information portals)
- Knowledge base of intelligent assistants such as Apple Siri and Amazon Alexa

Many applications (2)

As of today, Wikidata content has been used in many ways.

In research:

- Test data for KG-related algorithms
- Training data for machine-learning approaches
- Wikidata as a subject of study (social dynamics, internationality, biases, . . .)

Uses by Wikidata community:

- Software-supported error and vandalism detection
- Feature-based integration with other datasets
- Data-driven statistics as a measure of progress

What is Wikidata?

Wikidata is often described as "the free knowledge base that anyone can edit" or the "knowledge graph of Wikipedia"

It is useful to distinguish several of these aspects:

Wikidata is . . .

- **. . . a Wikimedia project** like Wikipedia and Wikimedia Commons; represented and supported by the Wikimedia Foundation (WMF)
- **. . . a dataset** that can be downloaded and freely used and distributed
- **. . . a website** through which the data can be viewed and modified
- **. . . a community** of volunteer editors that creates and controls all content

> "And like all uses of the word 'community,' you were never quite sure what or who it was." – Terry Pratchett (Jingo, 1997)

Principles of Wikidata

Several basic principles have guided the design of Wikidata:

- **Open editing:** Anyone can extend or modify content (as in Wikipedia); no user account or special skills needed
- **Community control:** The users decide what is stored and how it is represented; WMF only acts on legal or technical issues
- **Plurality:** There might not be one "truth" but several co-existing views; such complexity must be supported
- **Secondary data:** All content should be supported by external, primary sources; data is integrated and curated from a neutral point-of-view
- **Multi-lingual data:** One site serves all languages; labels are translated – content is the same for all
- **Easy access:** Technical and legal barriers for data re-use are minimised; sharing content is prioritised over controlling its use
- **Continuous evolution:** Incompleteness of content and technology are embraced; Wikidata remains "work in progress"

Two views on the Wikidata knowledge base

The website and its main data services expose Wikidata as a **document-centric knowledge base:**

- Data is grouped by subject entity (one page per entity)
- Documents are structured into different sections
- The order of content is (mostly) pre-served and shown

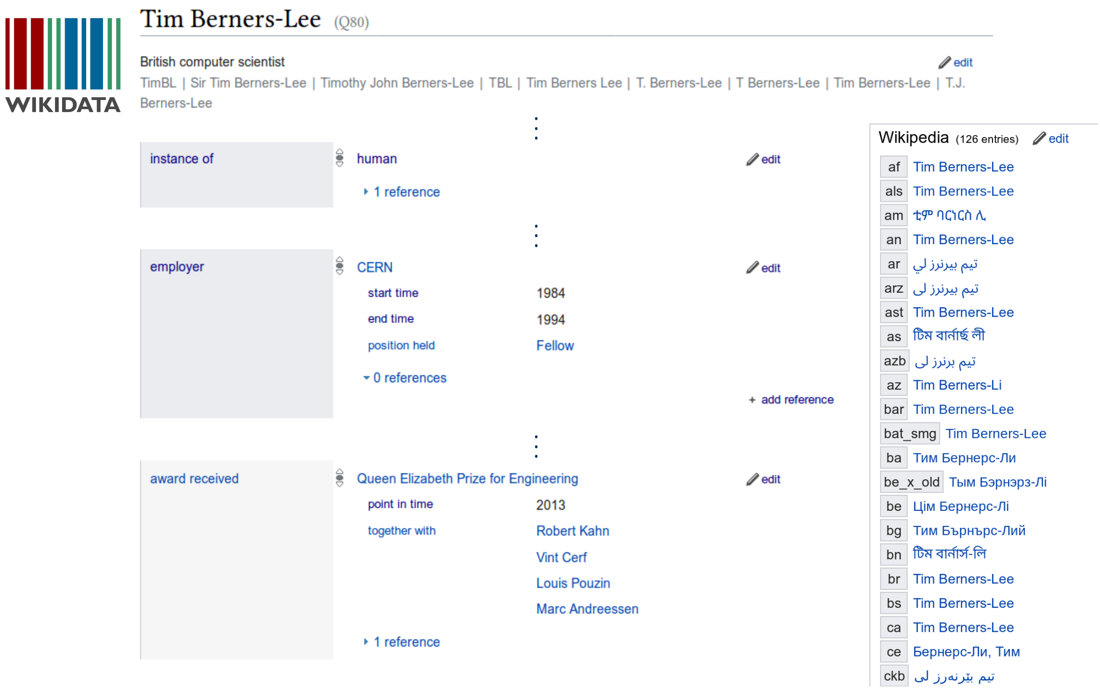
$\leadsto$ Useful for display and management

Conceptually and for most applications, Wikidata is a **graph-structured knowledge base:**

- Main content are binary relationships (from entities to entities/data values)
- Properties are first-class objects with a global scope and definition
- Order does not affect the meaning of statements

$\leadsto$ Useful for sharing and re-use

We will mostly view Wikidata as a knowledge graph.



Tim Berners-Lee (Q80)

British computer scientist ✎ edit

TimBL | Sir Tim Berners-Lee | Timothy John Berners-Lee | TBL | Tim Berners Lee | T. Berners-Lee | T Berners-Lee | Tim Berners-Lee | T.J. Berners-Lee

⋮

instance of — human ✎ edit
- ▸ 1 reference

⋮

employer — CERN ✎ edit
- start time 1984
- end time 1994
- position held Fellow
- ▾ 0 references
- + add reference

⋮

award received — Queen Elizabeth Prize for Engineering ✎ edit
- point in time 2013
- together with Robert Kahn
Vint Cerf
Louis Pouzin
Marc Andreessen
- ▸ 1 reference

Wikipedia (126 entries) ✎ edit

af	Tim Berners-Lee
als	Tim Berners-Lee
am	ቲም ባርነርስ ሊ
an	Tim Berners-Lee
ar	تيم بيرنرز لي
arz	تيم بيرنرز لى
ast	Tim Berners-Lee
as	টিম বাৰ্নাৰ্ছ লী
azb	تیم برنرز لی
az	Tim Berners-Li
bar	Tim Berners-Lee
bat_smg	Tim Berners-Lee
ba	Тим Бернерс-Ли
be_x_old	Тым Бэрнэрз-Лі
be	Цім Бернерс-Лі
bg	Тим Бърнърс-Лий
bn	টিম বার্নার্স-লি
br	Tim Berners-Lee
bs	Tim Berners-Lee
ca	Tim Berners-Lee
ce	Бернерс-Ли, Тим
ckb	تیم بێرنەرز لی

The content of Wikidata entity documents

The previous page shows the main kinds of content stored in Wikidata:

Entity ID: Entities are identified by language-independent ids (e.g., “Q80” for TimBL)

Terms header: Document pages start with a label, short description, and list of aliases in the user’s language (or best available language); terms can be entered for several hundred languages and writing systems

Statements: The main part of the page consists of sourced claims for several properties that an entity might have; statements may have a rank (normal, preferred, deprecated) to encode their current significance

Site links: Connections to pages on other Wikimedia projects realise entity-level information integration

Property pages use IDs of the form “P1234” and have an additional datatype declaration but no sitelinks. The other parts of the page are the same.

Wikidata’s IDs

Why does Wikidata use abstract (numeric) QIDs and PIDs rather than something more readable?

International
- Identifiers work for any language and cultural backgrounds

Stable
- Labels can change without IDs changing
- Multiple entities can have the same label
- IDs of deleted entities are never used again

Convenient
- Numeric IDs are quite short
- Uniform format is practical

How to find the ID of an item?

Main methods:

(1) Use the auto-completing search bar on wikidata.org

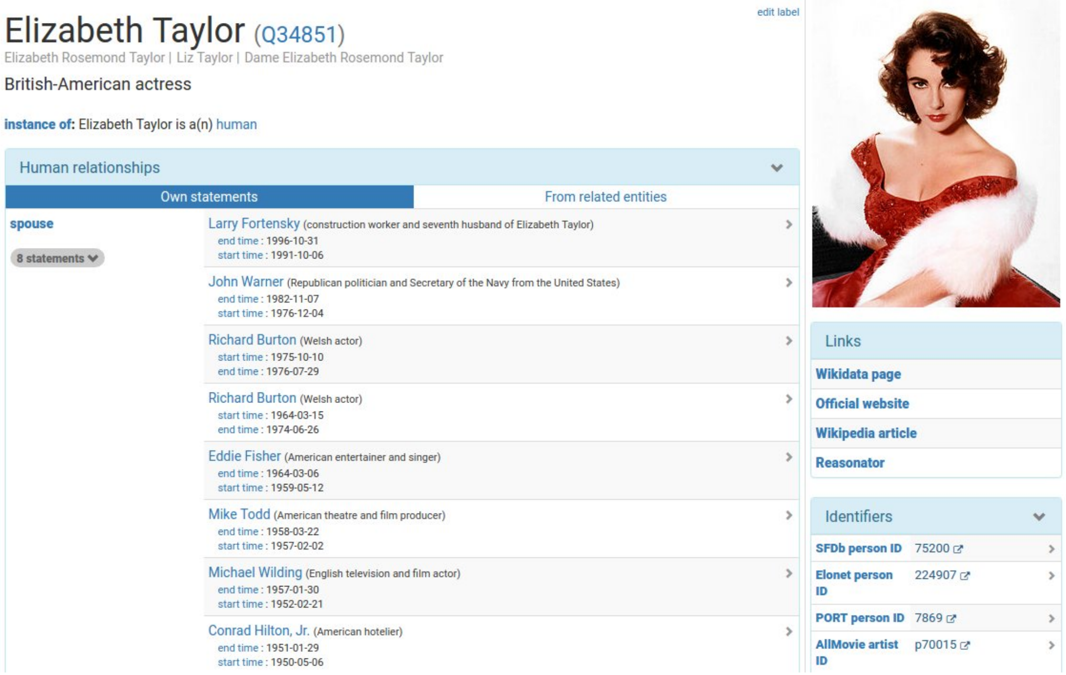
(2) Go to the item’s Wikipedia page and select “Wikdata item” from the sidebar

Several other projects have started to use Wikidata IDs for tagging and inter-linking.

Wikidata statements

Wikidata’s basic information units

- Built from Wikidata items (“CERN”, “Vint Cerf”), Wikidata properties (“award received”, “end time”), and data values (“2013”)
- Based on directed edges (“Tim Berners-Lee −employer→ CERN”)
- Annotated with property-value pairs (“end time: 1994”)
  - same property can have multiple annotation values (“together with: Robert Kahn, Vint Cerf, . . . ”)
  - same properties/values used in directed edges and annotations
- Items and properties can be subjects/values in statements
- Multi-graph



edit label

Elizabeth Taylor (Q34851)

Elizabeth Rosemond Taylor | Liz Taylor | Dame Elizabeth Rosemond Taylor

British-American actress

instance of: Elizabeth Taylor is a(n) human

Human relationships

Own statements | From related entities

spouse

8 statements

Larry Fortensky (construction worker and seventh husband of Elizabeth Taylor)
end time : 1996-10-31
start time : 1991-10-06

John Warner (Republican politician and Secretary of the Navy from the United States)
end time : 1982-11-07
start time : 1976-12-04

Richard Burton (Welsh actor)
start time : 1975-10-10
end time : 1976-07-29

Richard Burton (Welsh actor)
start time : 1964-03-15
end time : 1974-06-26

Eddie Fisher (American entertainer and singer)
end time : 1964-03-06
start time : 1959-05-12

Mike Todd (American theatre and film producer)
end time : 1958-03-22
start time : 1957-02-02

Michael Wilding (English television and film actor)
end time : 1957-01-30
start time : 1952-02-21

Conrad Hilton, Jr. (American hotelier)
end time : 1951-01-29
start time : 1950-05-06

Links

Wikidata page

Official website

Wikipedia article

Reasonator

Identifiers

SFDb person ID	75200
Elonet person ID	224907
PORT person ID	7869
AllMovie artist ID	p70015

Property types

Each Wikidata property has a datatype that defines which values it may take.

Available types (as of 2019):

- Entities of a fixed type (item, property, lexeme, sense, form)
- Quantities (including integers and numbers with units)
- Points in time (including imprecise dates and times in the distant past/future)
- Geographic coordinates (possibly on other astronomic bodies) and shapes
- URLs (actually including IRIs)
- Strings, and special strings (external identifier, media file name on Wikimedia Commons, tabular data file name on Wikimedia Commons, mathematical formula, musical notation)
- Texts in a specific language (similar to language-tagged RDF strings)

Property types cannot be changed once created.

Wikidata, RDF, and SPARQL

Wikidata in RDF

Wikidata is internally stored in the document-centric form using a JSON format

Data is converted to RDF for several purposes:

- Offering complete data dumps for external uses
- Providing entity-specific linked data exports via a Web API
- Importing data into Wikidata's SPARQL query service

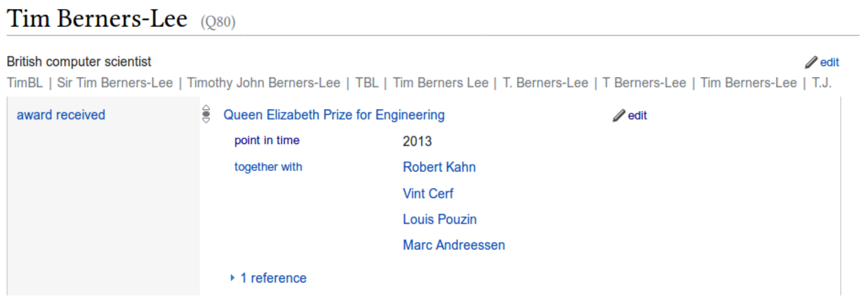
Wikidata's graph view has many commonalities with RDF:

- Based on directed, labelled, multi-graph
- Properties have own identity in graph
- Order and in-page context of statements does not matter

However, there are also some important differences:

- Wikidata statements can have annotations and references
- Wikidata property types do not correspond to XML Schema types
- Wikidata IDs are not immediately IRIs

Encoding statements in RDF (1)



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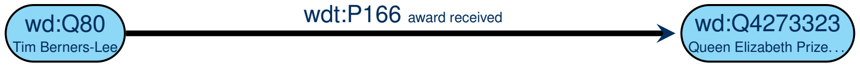
award received	Queen Elizabeth Prize for Engineering	✎ edit
	point in time	2013
	together with	Robert Kahn Vint Cerf Louis Pouzin Marc Andreessen
	▸ 1 reference	

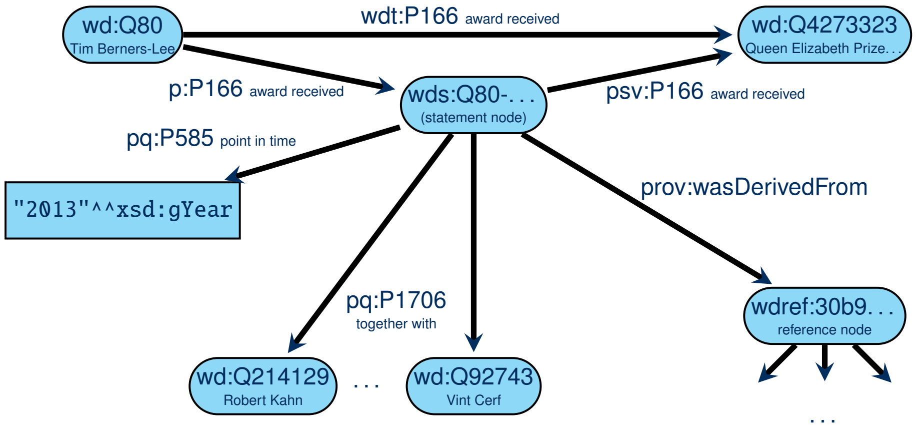


Where to store the annotations?

Note: For prefix declarations, see
`https://www.mediawiki.org/wiki/Wikibase/Indexing/RDF_Dump_Format`

Encoding statements in RDF (2)

We can encode statements in the style of reification:



Encoding statements in RDF (3)

Summary of statement RDF encoding:

- Each statement is represented by a resource in RDF
- Direct single-triple links from subject to value are added for many statements

  rule: direct links are generated for statements non-deprecated rank that are top-ranked among statements with the same subject and property
- Each Wikidata property turns into several RDF properties (for different uses in encoding)
- References and complex values are represented using auxiliary nodes (with a generated IRI)
- Values with units are additionally converted to a standard unit (if possible)

  the resulting normalised value is stored alongside the given value, using another set of RDF properties
- Order of qualifiers or statements is not represented in RDF

Useful sources:

- The complete Wikidata-to-RDF documentation is available online
  `https://www.mediawiki.org/wiki/Wikibase/Indexing/RDF_Dump_Format`
- Any item can be viewed in RDF in the browser using URLs such as
  `http://www.wikidata.org/wiki/Special:EntityData/Q80.ttl`

Finishing the RDF encoding

Statements in Wikidata:

- Constitute the largest part of the RDF data
- RDF-encoding introduces over 50K RDF properties

Encoding other parts of Wikidata:

- Labels, descriptions, aliases are encoded as RDF literals with language tags, linked from subject with rdfs:label, schema:description, and skos:altLabel, respectively
- Sitelinks are encoded using property schema:about (from article page URL to Wikidata entity IRI)

Available RDF data:

- Full dumps are generated weekly (currently >8.5B triples, 59GiB gzipped Turtle) For download see `https://dumps.wikimedia.org/wikidatawiki/entities/`
- Linked data exports are provided through content negotiation

  Alternatively, directly use data URLs like `http://www.wikidata.org/wiki/Special:EntityData/Q80.nt`

SPARQL on Wikidata

Wikidata SPARQL Query Service (WDQS):

- Official query service since mid 2015
- User interface at `https://query.wikidata.org/`
  - Query editing support (auto-completion, suggestions. examples)
  - Support for many different result visualisations
- All the data (8.5B triples), live (latency<60s)
- Very liberal configuration:
  - 60sec timeout
  - No limit on result size
  - No limit on parallel queries, but CPU-time budget per client
- Extra SERVICEs in SPARQL (geo, Wikipedia API, labels, ...)

WDQS: Usage

SPARQL is widely used on Wikidata:

- >100M requests per month (3.8M per day) in 2018
- Many applications using SPARQL as API in the back-end (e.g., mobile apps)
- Useful for advanced content analysis and data journalism
- Also playing an important role in Wikidata editing and quality control

. . . while keeping acceptable quality of service:

- In 2018: 50% of queries answered in <40ms (95% in <440ms; 99% in <40s)
- . . . and less than 0.05% of queries timed out
- Service has never been down so far
- However: keeping up with Wikidata's growth becomes harder (⇝ synchronisation lags >1min; more query timeouts)

Query statistics from Malyshev et al., "Getting the Most out of Wikidata: Semantic Technology Usage in Wikipedia's Knowledge Graph", ISWC 2018

System setup

What is necessary to provide a public online service at this scale?

WDQS runs a typical master-slave setup with a primary storage server and several secondary query servers.

- Currently (2019), three commodity query servers are used for WDQS (+3 more for geographic backup)
- Wikidata's primary servers use a typical LAMP stack (Linux, Apache, MariaDB, PHP)
- BlazeGraph used as free and open-source graph database for WDQS
- Standard HTTP cache (Varnish) for speeding up answers
- Custom script used to monitor changes and update the database accordingly
- Query servers are independent; incoming requests distributed by load balancing (LVS)

All software used is free & open source

WDQS core components: `https://github.com/wikimedia/wikidata-query-rdf`

Summary

Wikidata, the knowledge base of Wikipedia, is a freely available knowledge graph

Wikidata supports a document-centric and a graph-centric perspective

Content can be converted to RDF and a public SPARQL query service is available

What's next?

- More SPARQL query features
- Further background on SPARQL complexity and semantics
- Graphs beyond RDF