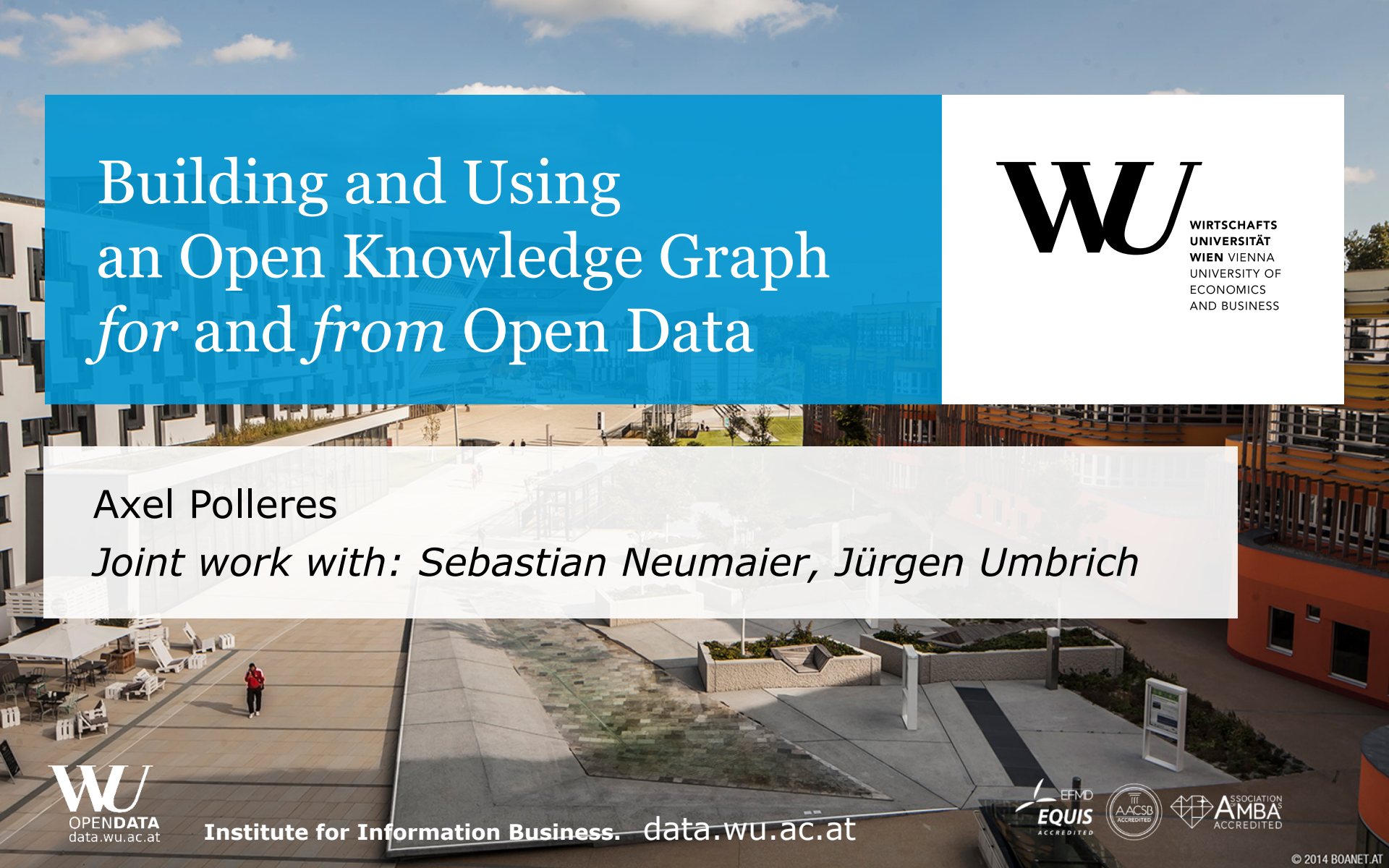
Building and Using an Open Knowledge Graph *for* and *from* Open Data

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

Axel Polleres

Joint work with: Sebastian Neumaier, Jürgen Umbrich



OPENDATA data.wu.ac.at

Institute for Information Business. data.wu.ac.at

EFMD EQUIS ACCREDITED · AACSB ACCREDITED · ASSOCIATION OF MBAS ACCREDITED

What is a Knowledge Graph?

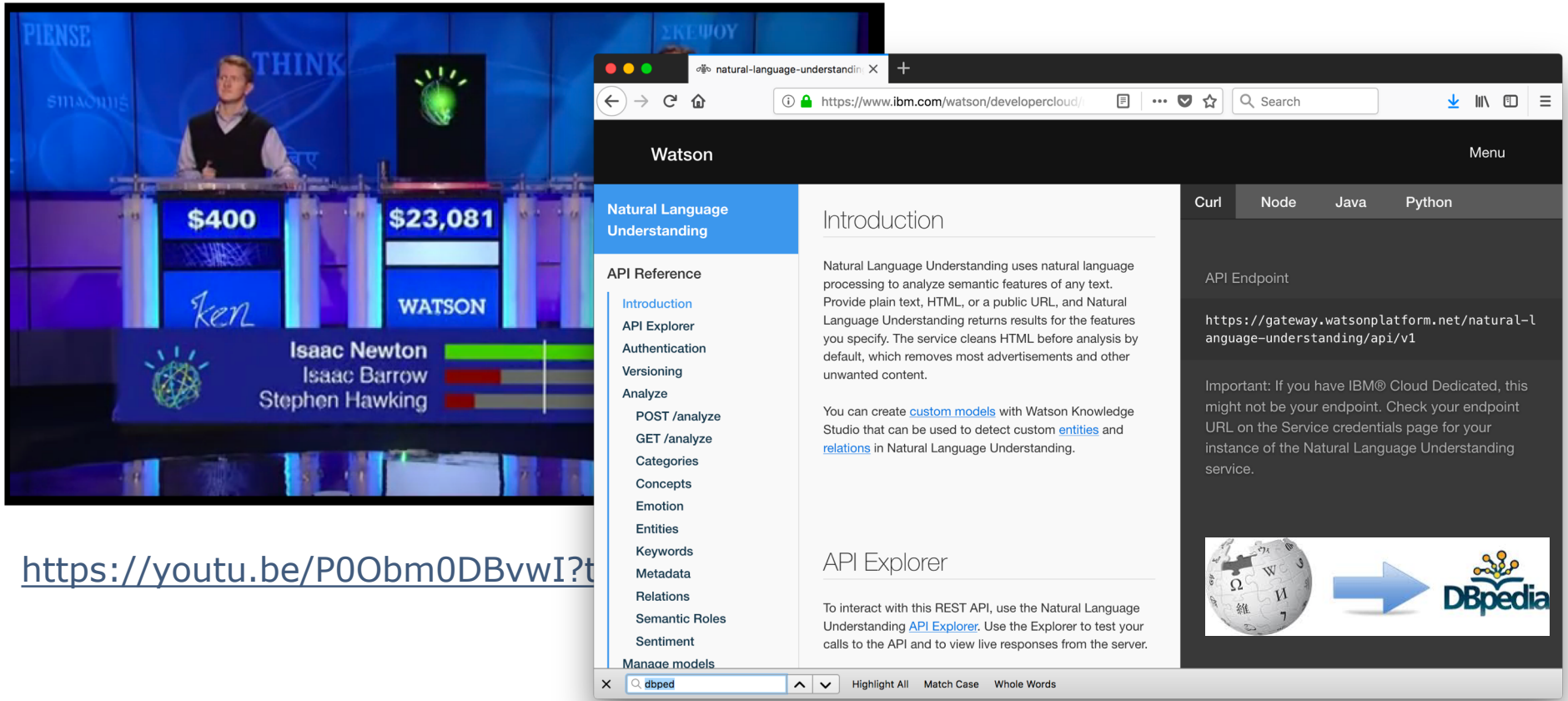
What is Open Data?

How do they connect?

2 applications for using Knowledge Graphs & Linked Data for *Open Data Search*!

What is a Knowledge Graph?

Probably I don’t need to ask this here…



https://youtu.be/P0Obm0DBvwI?t

But seriously:
What IS a Knowledge Graph?

WU WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

… good question!

Google

Official Blog

Insights from Googlers into our products, technology, and the Google culture

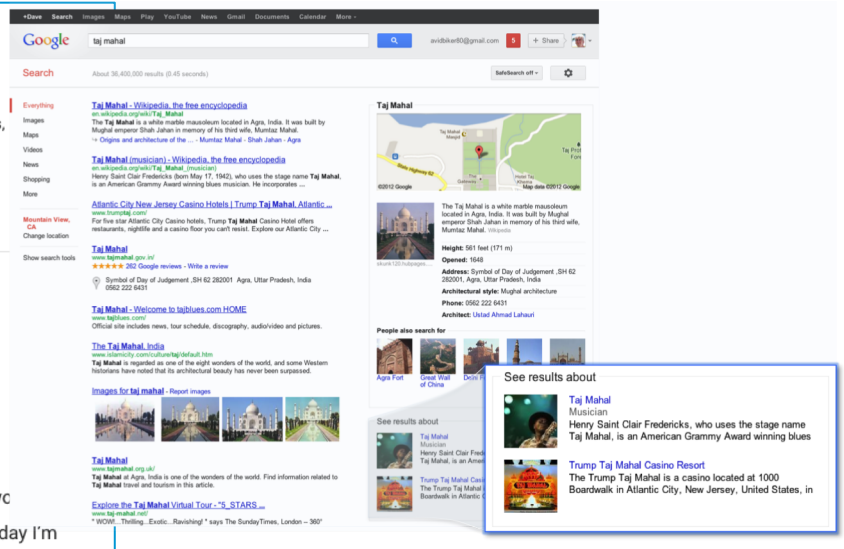
Introducing the Knowledge Graph: things, not strings

May 16, 2012

Cross-posted on the Inside Search Blog

Search is a lot about discovery—the basic human need to learn and broaden yc horizons. But searching still requires a lot of hard work by you, the user. So today I'm really excited to launch the Knowledge Graph, which will help you discover new information quickly and easily.

Take a query like [taj mahal]. For more than four decades, search has essentially been about matching keywords to queries. To a search engine the words [taj mahal] have been just that—two words.



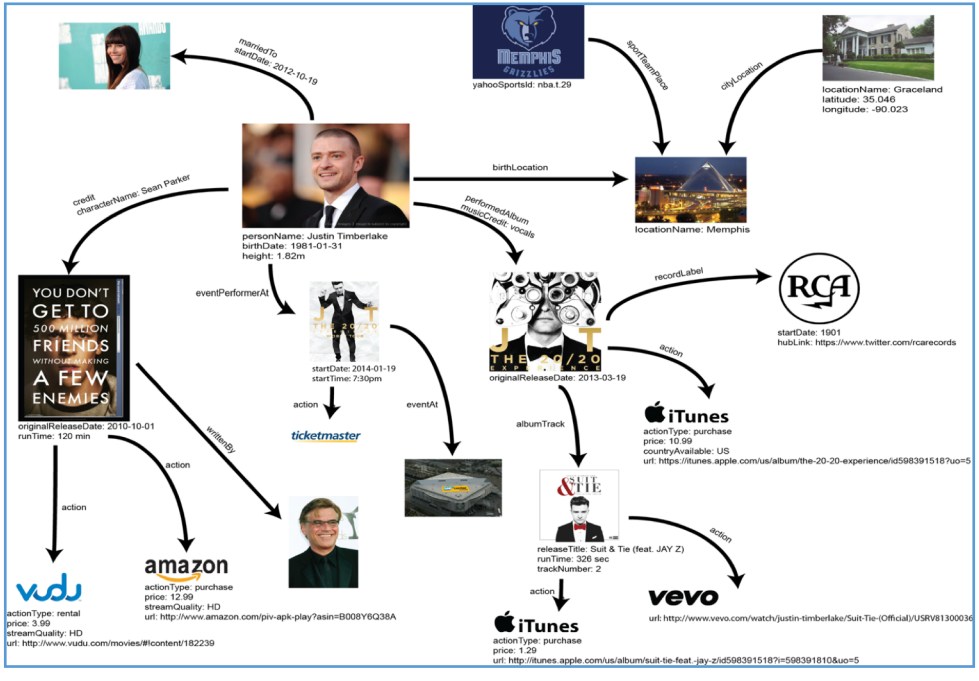
Says more what a KG **does** than what it **is**…
"interesting things and [understanding their] relationships [to improve Search]"

What is a Knowledge Graph?

- Semantic Search: Yahoo's knowledge graph…

Source: What happened to the Semantic Web? Peter Mika, Keynote at ACM Hypertext, July 5, 2017

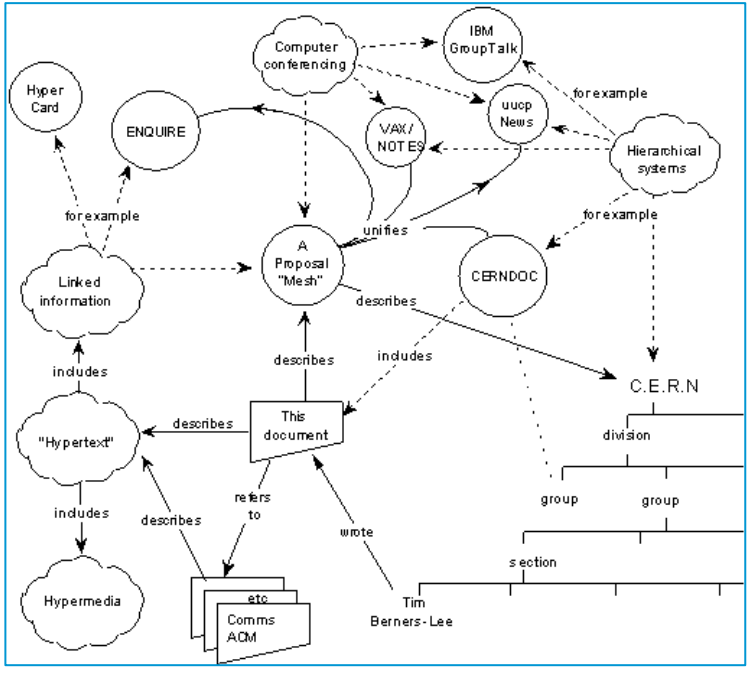
https://www.slideshare.net/pmika/what-happened-to-the-semantic-web



What is a Knowledge Graph?

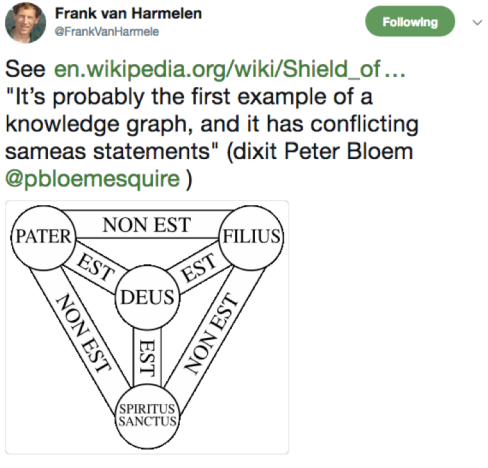
Doesn't look too different from that one?

Source: https://www.w3.org/History/1989/proposal.html Tim Berners-Lee, 1989



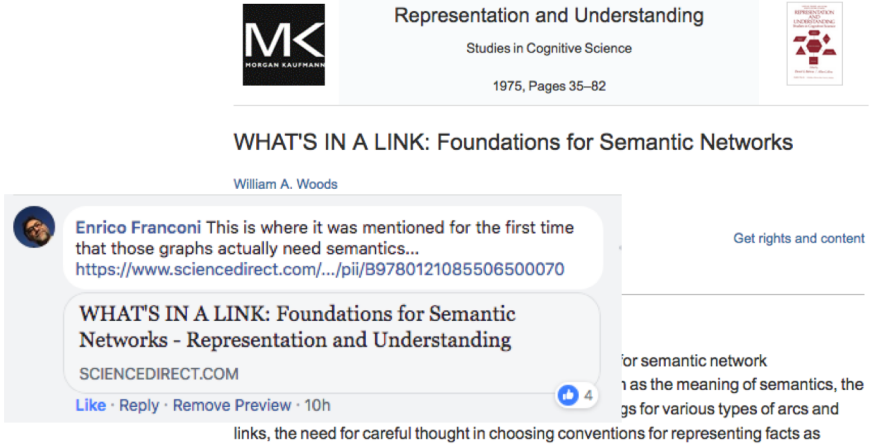
What is a Knowledge Graph?

- Some more random proposals of what was the ”first knowledge graph from social media… :



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

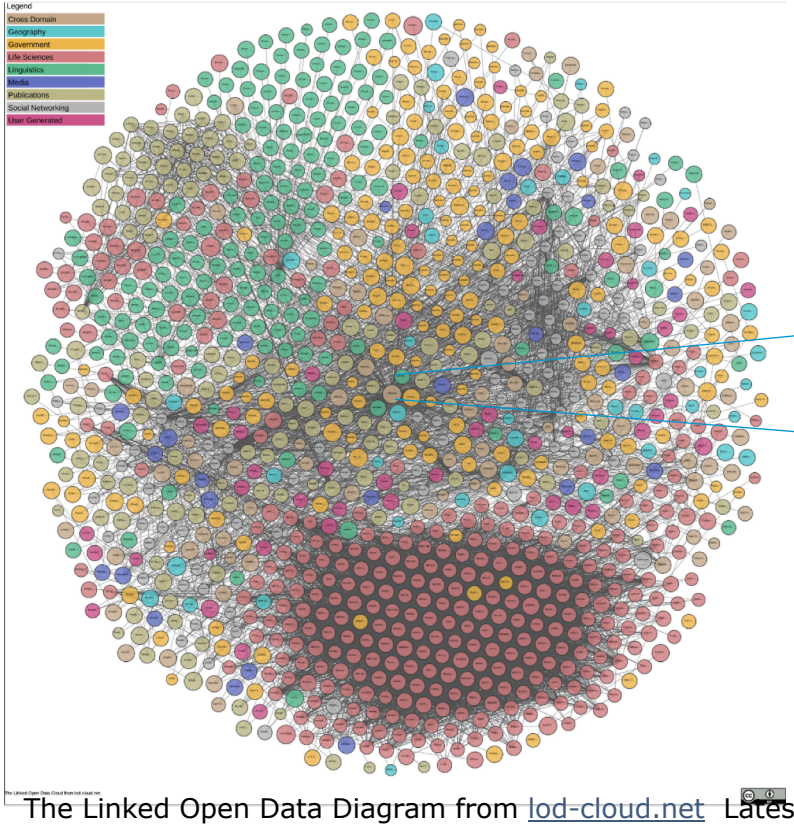
(via Enrico Franconi)



https://www.sciencedirect.com/science/article/pii/B9780121085506500070

Others: KL-ONE, CYC …

When we hear about Open Data and Knowledge Graphs… many think about Linked Open Data…



DBpedia

The Linked Open Data Diagram from lod-cloud.net Latest release 04-30-2018- 1184 Datasets

So What is actually Linked Data…?

https://www.w3.org/community/webize/2014/01/17/what-is-5-star-linked-data/

★	Available on the web (whatever format) *but with an open licence, to be Open Data*
★★	Available as machine-readable structured data (e.g. excel instead of image scan of a table)
★★★	as (2) plus non-proprietary format (e.g. CSV instead of excel)
★★★★	All the above plus, Use open standards from W3C (RDF and SPARQL) to identify things, so that people can point at your stuff
★★★★★	All the above, plus: Link your data to other people's data to provide context

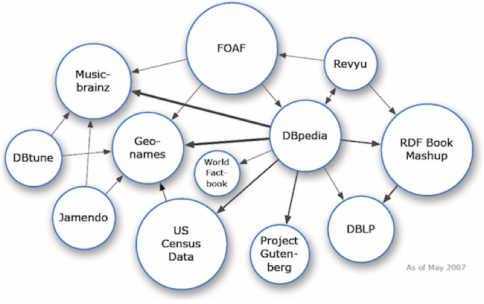
+

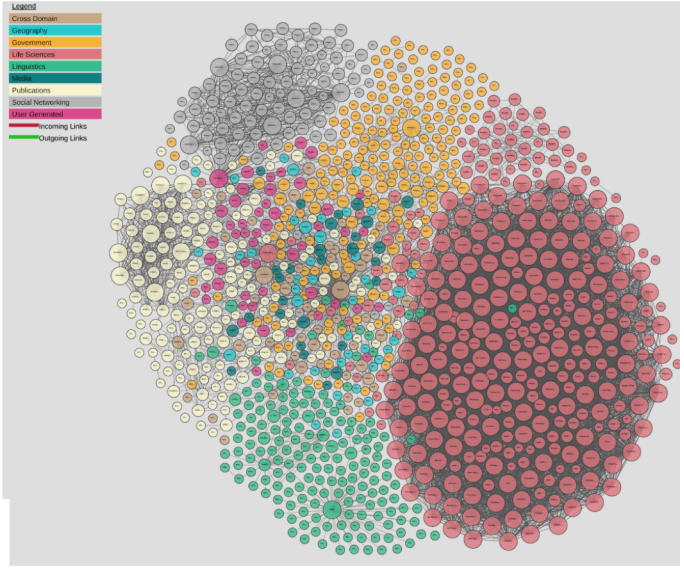
Linked Data Principles

- **LDP1:** use URIs as names for things
- **LDP2:** use HTTP URIs so those names can be dereferenced
- **LDP3:** return useful – RDF? – information upon dereferencing those URIs
- **LDP4:** include links using externally dereferenceable URIs.

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

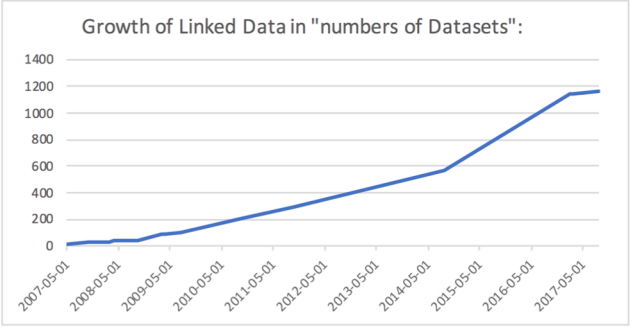
Linked Open Data... growth since ~10 years





Linking Open Data cloud diagram 2007-2017, by Andrejs Abele, John P. McCrae, Paul Buitelaar, Anja Jentzsch and Richard Cyganiak. http://lod-cloud.net/

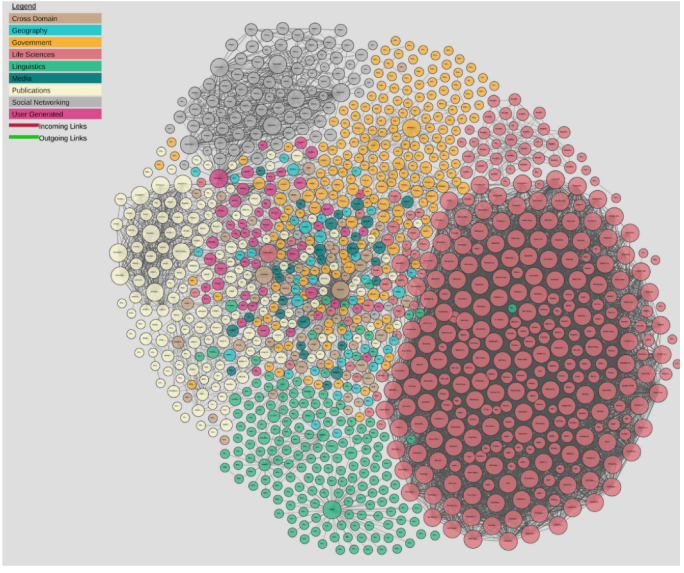
2017-08-22	1163
2017-02-20	1139
2017-01-26	1146
2014-08-30	570
2011-09-19	295
2010-09-22	203
2009-07-14	95
2009-03-27	93
2009-03-05	89
2008-09-18	45
2008-03-31	34
2008-02-28	32
2007-11-10	28
2007-11-07	28
2007-10-08	25
2007-05-01	12



Linked Open Data…

Summary:

- Web inspired Data exchange Format (RDF)
- **Open Standards and Principles to build**, publish and interlink decentralized **Knowledge Graphs**
- Did in fact inspire many other Knowledge Graphs!



Linking Open Data cloud diagram 2007-2017, by Andrejs Abele, John P. McCrae, Paul Buitelaar, Anja Jentzsch and Richard Cyganiak. http://lod-cloud.net/

- But: **Open Data** is a lot more than Linked Open Data…

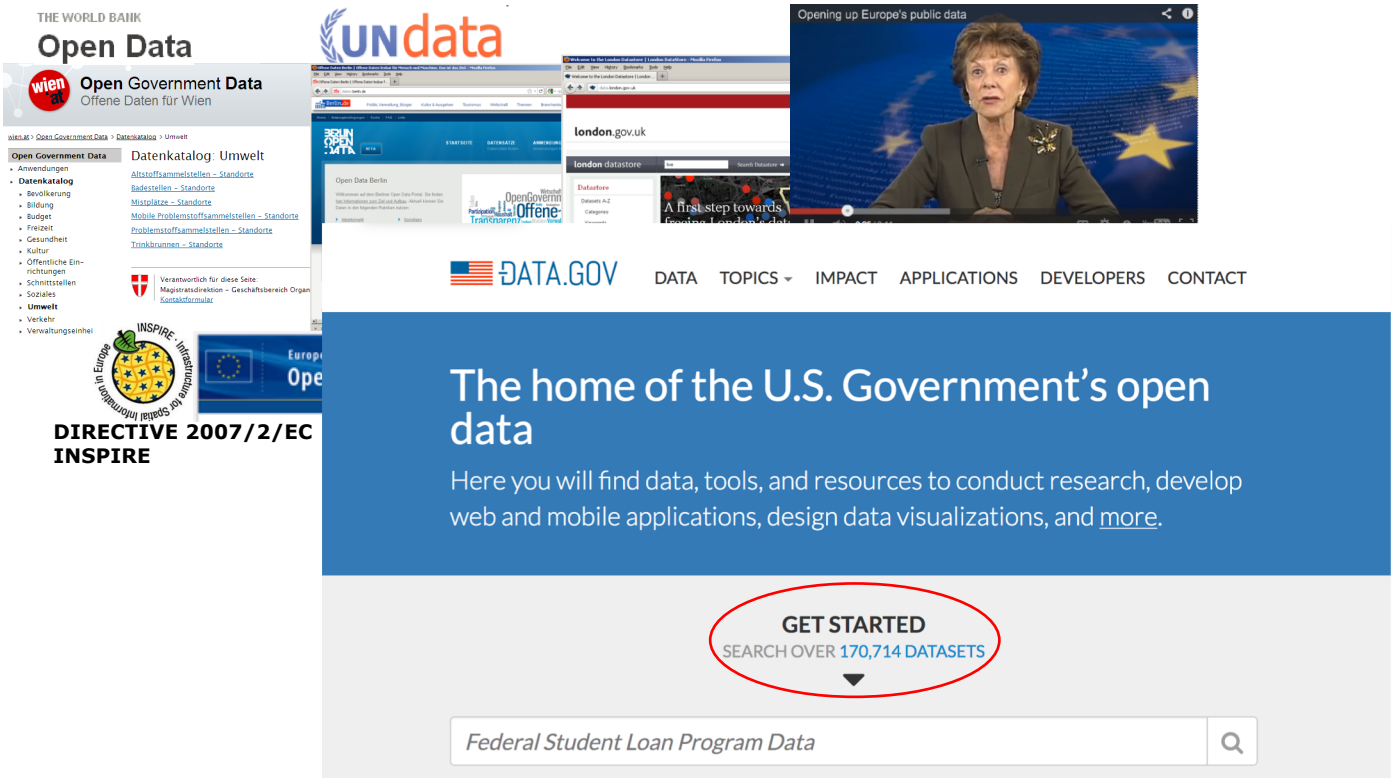
What is a Knowledge Graph?

What is Open Data?

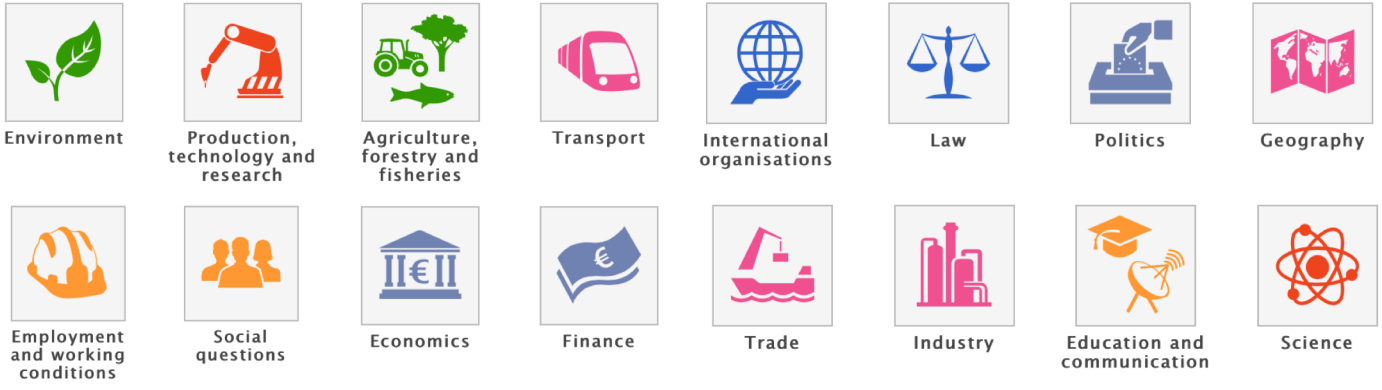
How do they connect?

Open Data is a Global Trend!

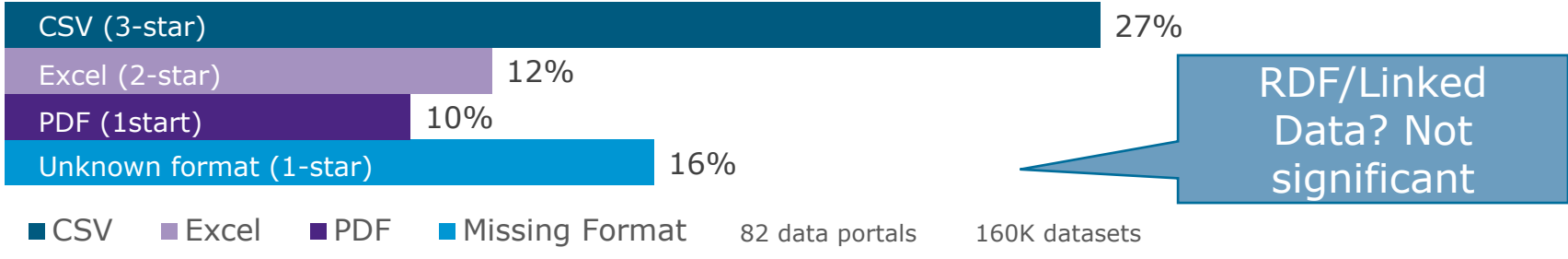
- EU & Austria, but also the (previous) US and UK administration are/were pushing Open Data!



(Structured) Open Data comes in various ways



- Available data is only partially structured and not linked [1]:



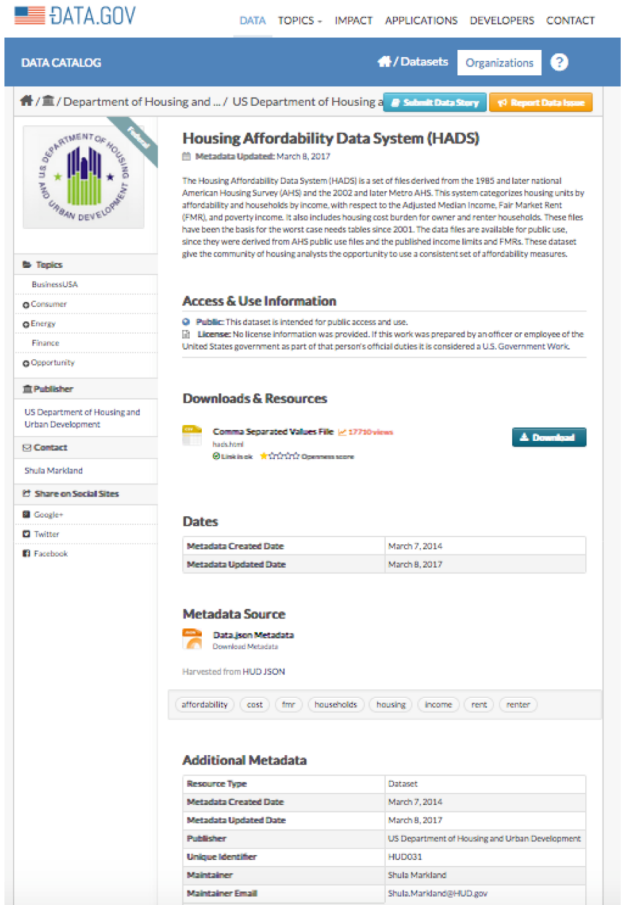
[1] Umbrich, J., Neumaier, S., Polleres, A.: Quality assessment & evolution of open data portals. International Conference on Open and Big Data (2015)

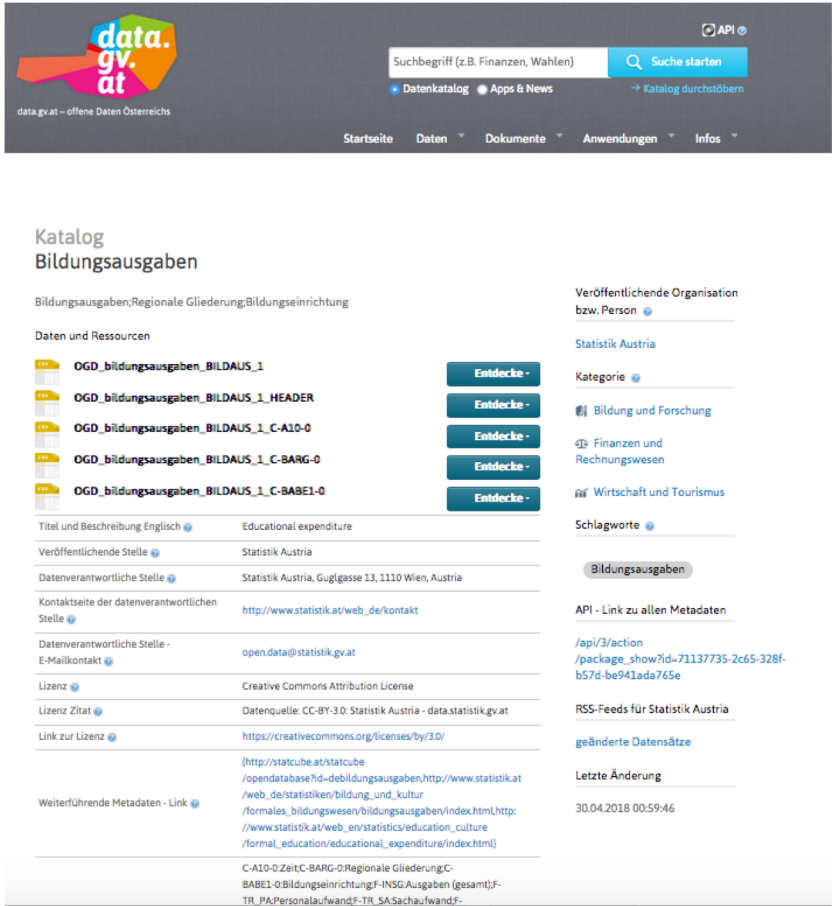
Open Data as a Global Trend:

Country	URL	Datasets
United States	data.gov	170.7k
Canada	open.canada.ca	79.1k
UK	data.gov.uk	45.1k
France	www.data.gouv.fr	34.2k
Russia	opengovdata.ru	30.3k
Japan	data.go.jp	21k
Italy	dati.gov.it	20.4k
Germany	govdata.de	19.8k

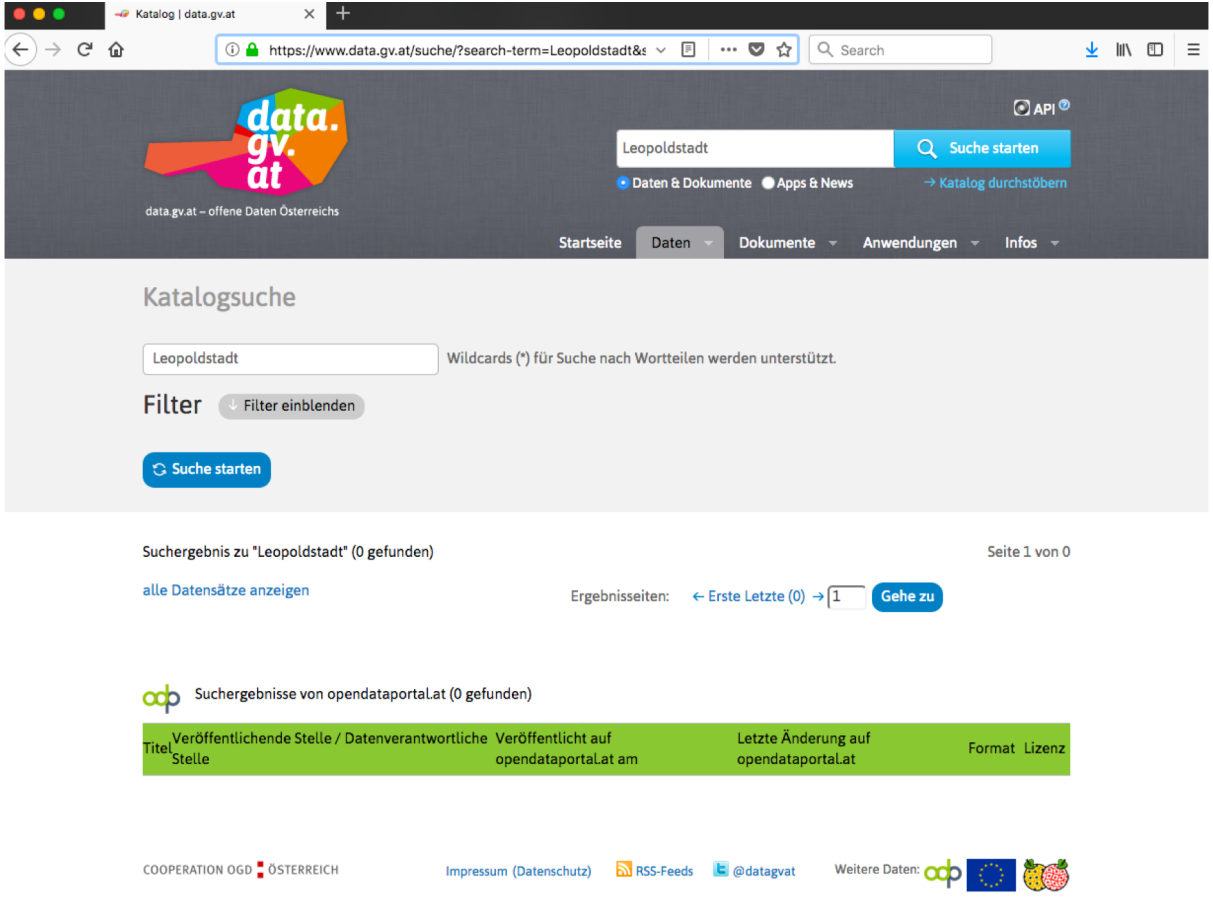
Data portals of the G8 countries

Different portals…





What do you find on Open Data Portals?

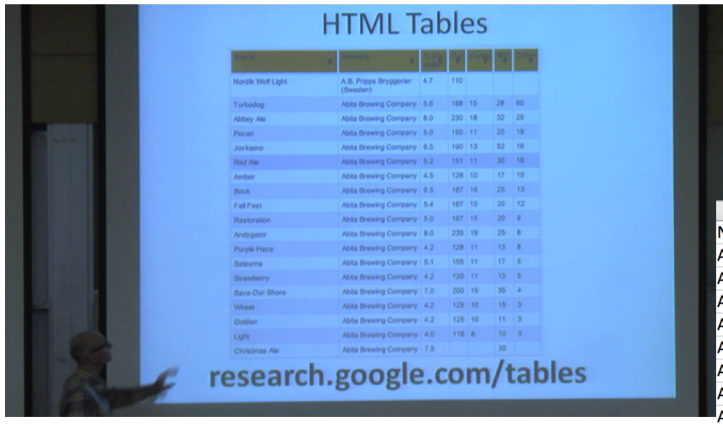


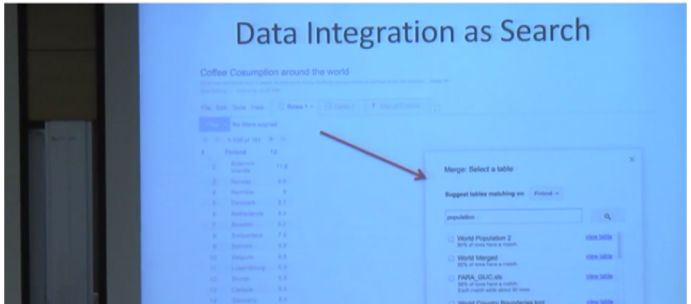
Not too much!

Why is Search in Open Data a problem?

https://www.youtube.com/watch?v=kCAymmbYIvc

Structured Data in Web Search by Alon Halevy





vs.

B	C	D	E	F	G	H	I
NUTS2	NUTS3	DISTRICT_CODE	SUB_DISTRICT_CODE	POP_TOTAL	POP_MEN	POP_WOMEN	REF_DATE
AT13	AT130	90101	0	16131	7726	8405	01.01.2014
AT13	AT130	90201	0	99597	48650	50947	01.01.2014
AT13	AT130	90301	0	86454	41085	45369	01.01.2014
AT13	AT130	90401	0	31452	14903	16549	01.01.2014
AT13	AT130	90501	0	53610	26299	27311	01.01.2014
AT13	AT130	90601	0	30613	14833	15780	01.01.2014
AT13	AT130	90701	0	30792	14703	16089	01.01.2014
AT13	AT130	90801	0	24279	11855	12424	01.01.2014
AT13	AT130	90901	0	40528	19286	21242	01.01.2014
AT13	AT130	91001	0	186450	91638	94812	01.01.2014
AT13	AT130	91101	0	93440	45541	47899	01.01.2014
AT13	AT130	91201	0	90874	43752	47122	01.01.2014

***Open Data Search is hard**...*

a) No natural language „cues" like in Web tables...

b) Existing knowledge graphs don't cover the domain of "Open Data" well

c) Open Data is not properly geo-referenced

2 applications for using Knowledge Graphs & Linked Data for Open Data Search!

WU WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- What we do: 2 approaches how knowledge graphs could help to solve the Open Data search problem (aside the obvious):
  1. Hierarchical labelling of Labeling of numeric data
  2. Hierarchical labelling of Spatio-Temporal entities

Example Table

federal state	*district*	*year*	*sex*	*population*
Upper Austria	Linz	2013	male	98157
Upper Austria	Steyr	2013	male	18763
Upper Austria	Wels	2013	male	29730
...	...	...	...	...

Open Data CSVs look more like this

NUTS2	*LAU2_NAME*	*YEAR*	*SEX*	*P_TOTAL*
AT31	Linz	2013	1	98157
AT31	Steyr	2013	1	18763
AT31	Wels	2013	1	29730
…	…		…	…

Source: https://www.data.gv.at/katalog/dataset/e108dcc3-1304-4076-8619-f2185c37ef81

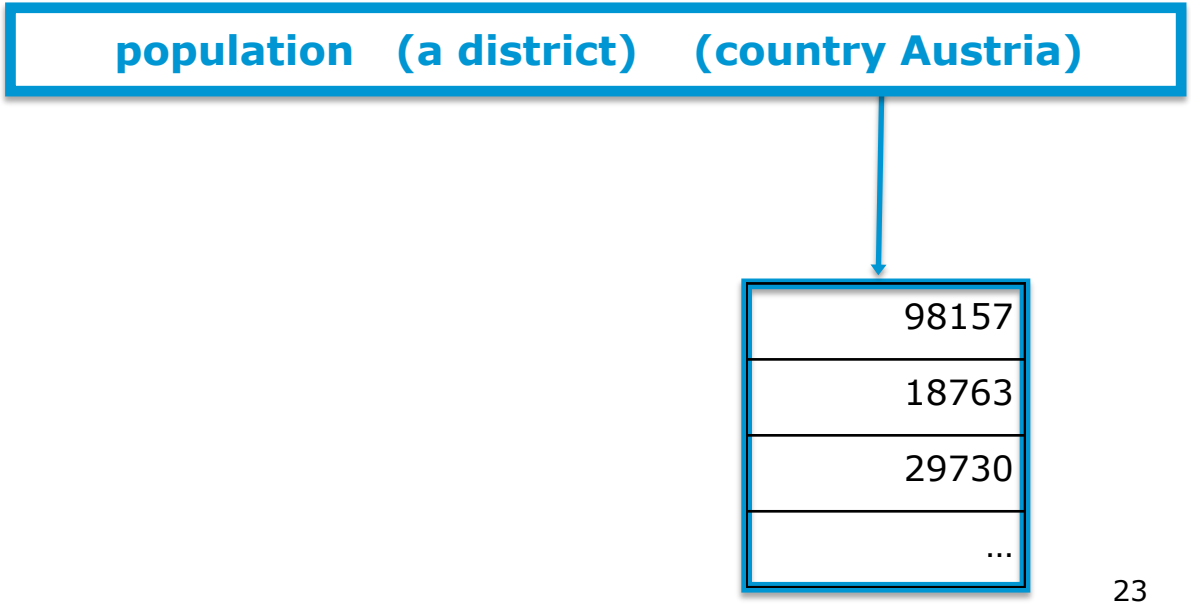
Why not use the numeric values?

- Identifying the most likely semantic label for a bag of numerical values
- Deliberately ignore surroundings

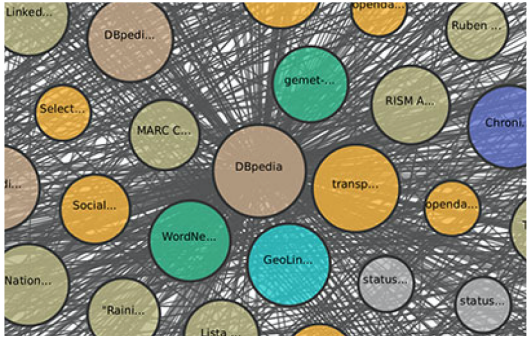
NUTS2	*LAU2_NAME*	*YEAR*	*SEX*	*P_TOTAL*
AT31	Linz	2013	1	98157
AT31	Steyr	2013	1	18763
AT31	Wels	2013	1	29730
…	…		…	…

Why not use numeric values?

- Identifying the most likely semantic label for a bag of numerical values
- Deliberately ignore surroundings



Background Knowledge Graph

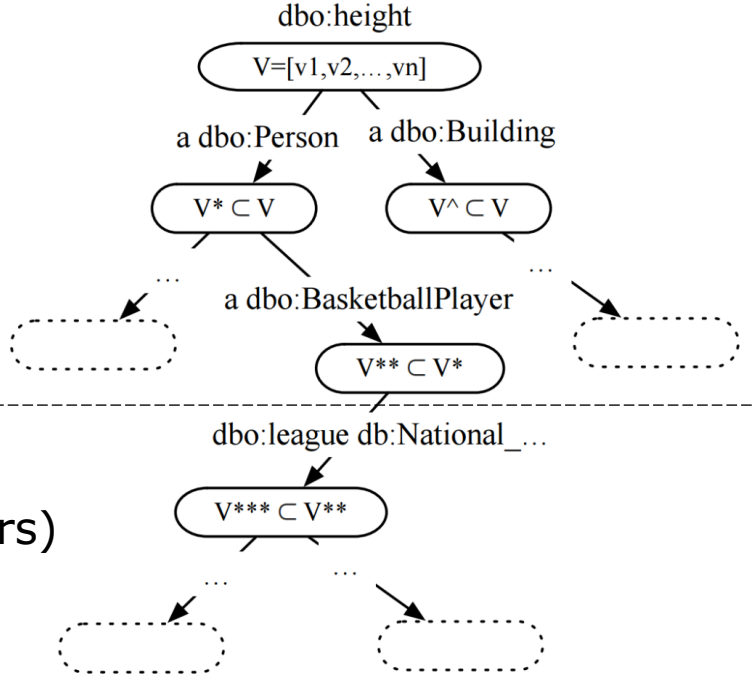


What's in there?

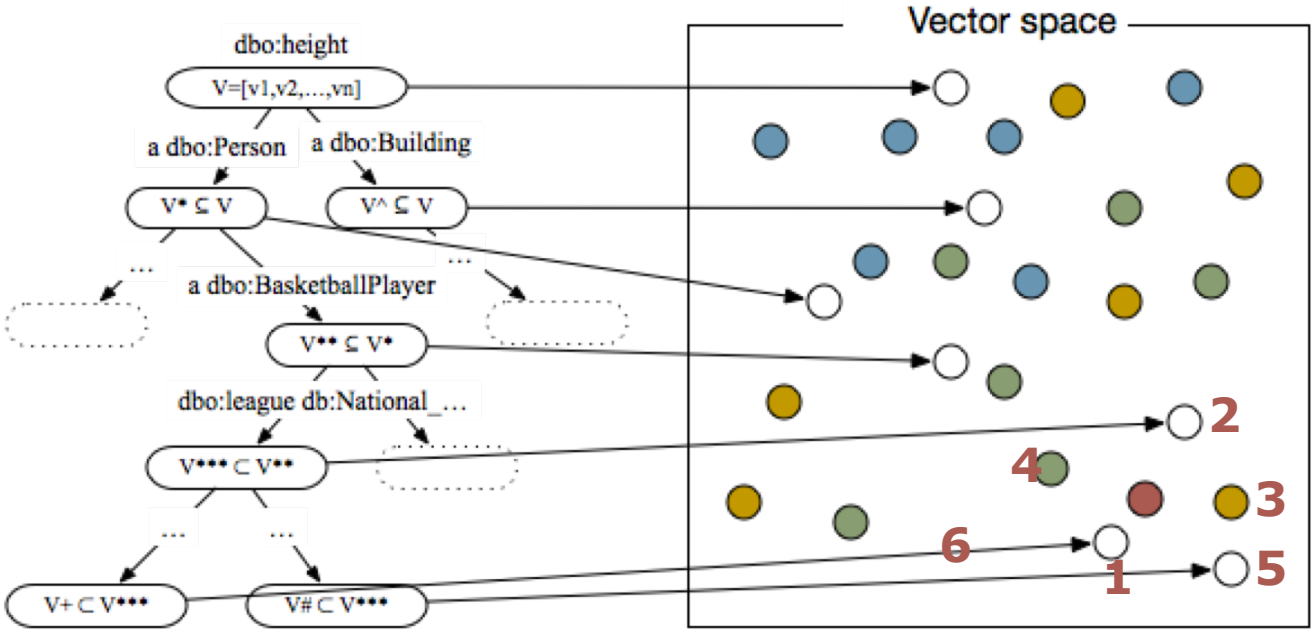
- Cities
  - **Population**
  - **Area**
  - Country
  - Location (**Coordinates)**
  - Economic indicators
  - …
- Organisations:
  - **Revenues**
  - Board members
  - **…**
- Persons (e.g. celebrities, sports)
  - Name
  - Profession
  - **Height**
- Landmarks (e.g. famous buildings)
  - **Country**
  - **Location**
  - **Height**
- Events
  - **Dates**
  - **Location**

Background Knowledge Graph

- Find properties with **numerical range**
- Hierarchical clustering approach
- Two hierarchical layers:
  - **Type** hierarchy (using OWL classes)
  - **Property-object** hierarchy (shared property-object pairs)



Label based on Nearest Neighbors



Example OD Labelling

populationTotal (a Settlement)
populationDensity (a City)

NUTS1	NUTS2	NUTS3	DISTRICT_CODE	T	WV	WK	BZ	SPR	WBER	ABG.	UNG.	OEVP	SPOE	FPOE	GRUE	BZOE	NEOS
AT1	AT13	AT130		1	9	0	0	0	1163061	503284	9386	81974	136391	89963	103249	1516	44891
AT1	AT13	AT130		2	9	1	0	0	111279	52674	774	9344	12395	6482	14154	114	5412
AT1	AT13	AT130		2	9	2	0	0	98379	51785	646	10324	10236	4700	15398	124	6569
AT1	AT13	AT130		2	9	3	0	0	110527	45483	810	5317	13304	7816	10944	115	3613
AT1	AT13	AT130		2	9	4	0	0	229521	84387	1953	10097	27922	21091	11631	256	5299
AT1	AT13	AT130		2	9	5	0	0	212262	97755	1806	18703	25314	16613	19333	324	9175
AT1	AT13	AT130		2	9	6	0	0	175288	82790	1321	17560	19059	11765	18996	242	8389
AT1	AT13	AT130		2	9	7	0	0	225805	88410	2076	10629	28161	21496	12793	341	6434
AT1	AT13	AT130	90301	3	9	1	3	0	57528	27320	412	4938	6586	3567	6969	68	2789
AT1	AT13	AT130	90401	3	9	1	4	0	21000	11027	138	2401	2253	1068	3082	26	1277
AT1	AT13	AT130	90501	3	9	1	5	0	32751	14327	224	2005	3556	1847	4103	20	1346

Source: http://data.wu.ac.at/iswc2016_numlabels/submission/col14.html

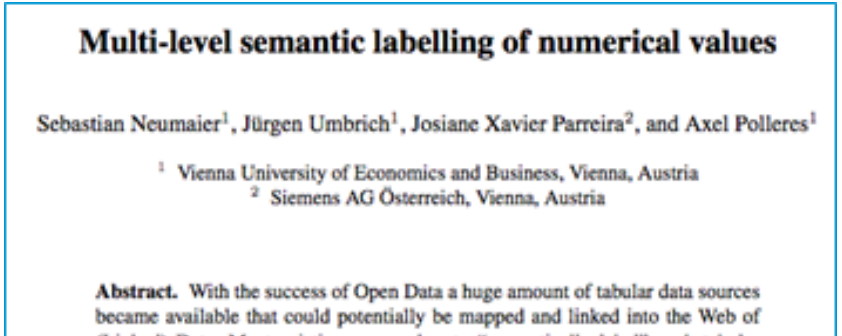
Lessons learned

- We can assign fine-grained semantic labels
  - **If there is enough evidence in BK**
- *However*: Missing domain knowledge for labelling OD

Future work:

- Complementary to existing approaches (column header labeling, entity linking and relation extraction)
- Combined approaches may improve results
- Focusing on *core dimensions* of *specific domains* e.g. city data, maye more promising than "general" value labeling.

International Semantic Web conference 2016:



Multi-level semantic labelling of numerical values

Sebastian Neumaier[1], Jürgen Umbrich[1], Josiane Xavier Parreira[2], and Axel Polleres[1]

[1] Vienna University of Economics and Business, Vienna, Austria
[2] Siemens AG Österreich, Vienna, Austria

Abstract. With the success of Open Data a huge amount of tabular data sources became available that could potentially be mapped and linked into the Web of

What else can we do/use?

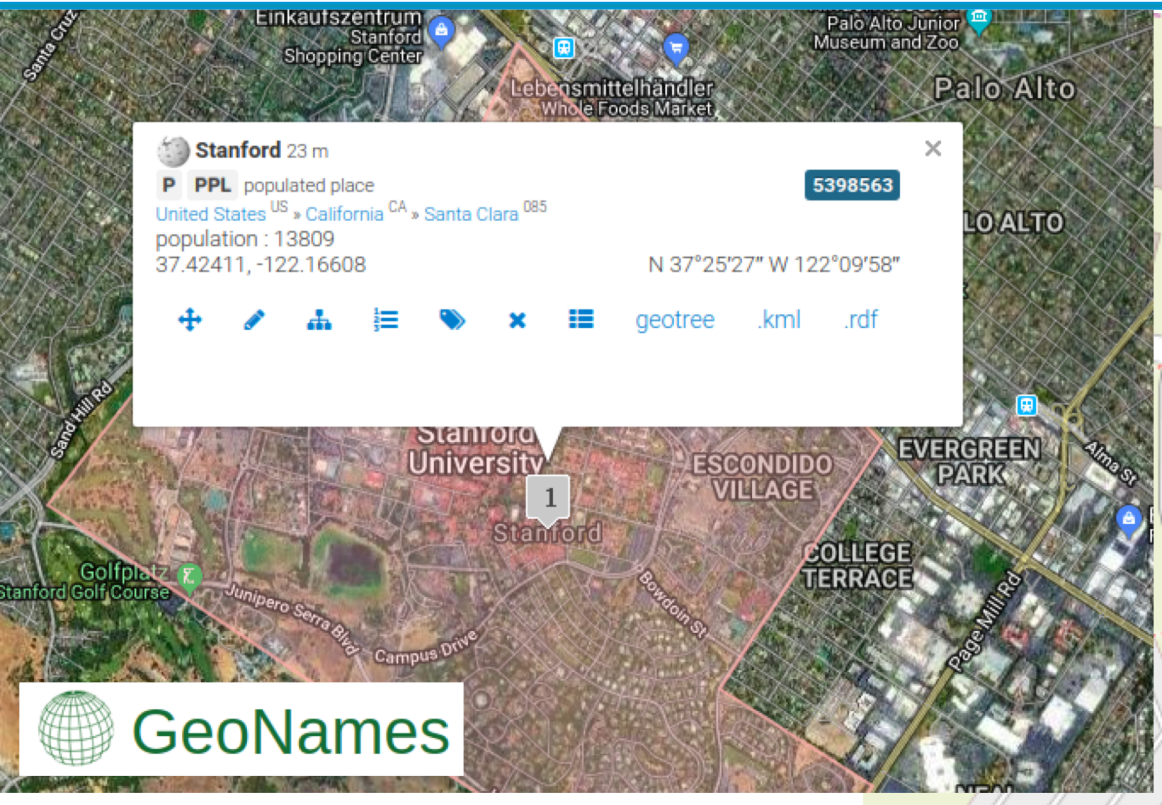
Focus on specific dimensions:

- Particularly **temporal** and **geospatial** queries require better support [2]

NUTS2	*LAU2_NAME*	*YEAR*	*SEX*	*AGE_TOTAL*
AT31	Linz	2013	1	98157
AT31	Steyr	2013	1	18763
AT31	Wels	2013	1	29730
…	…		…	…

[2] Emilia Kacprzak, et al.: A Query Log Analysis of Dataset Search. International Conference on Web Engineering (2017)

Available Geospatial Knowledge Bases



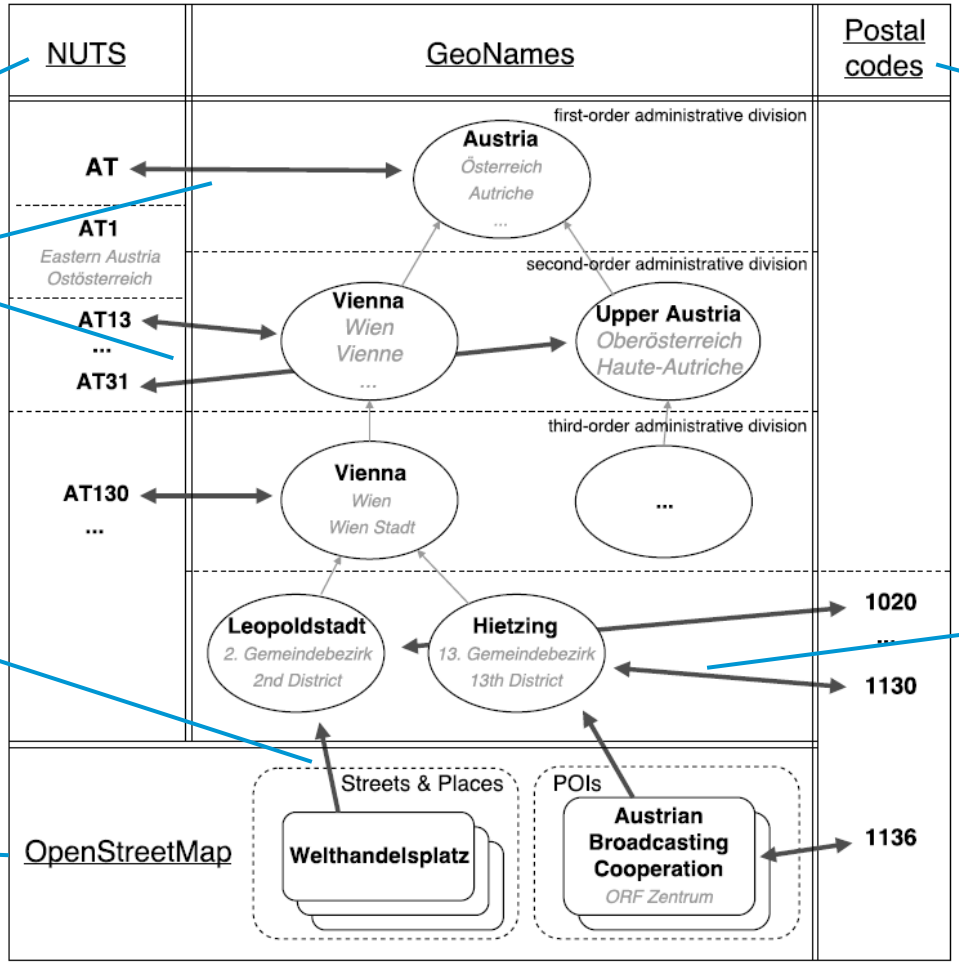
Geo-Knowledge Graph Construction

European Classification of Territorial Units

Wikidata links

Mapping OSM entities to GeoNames regions

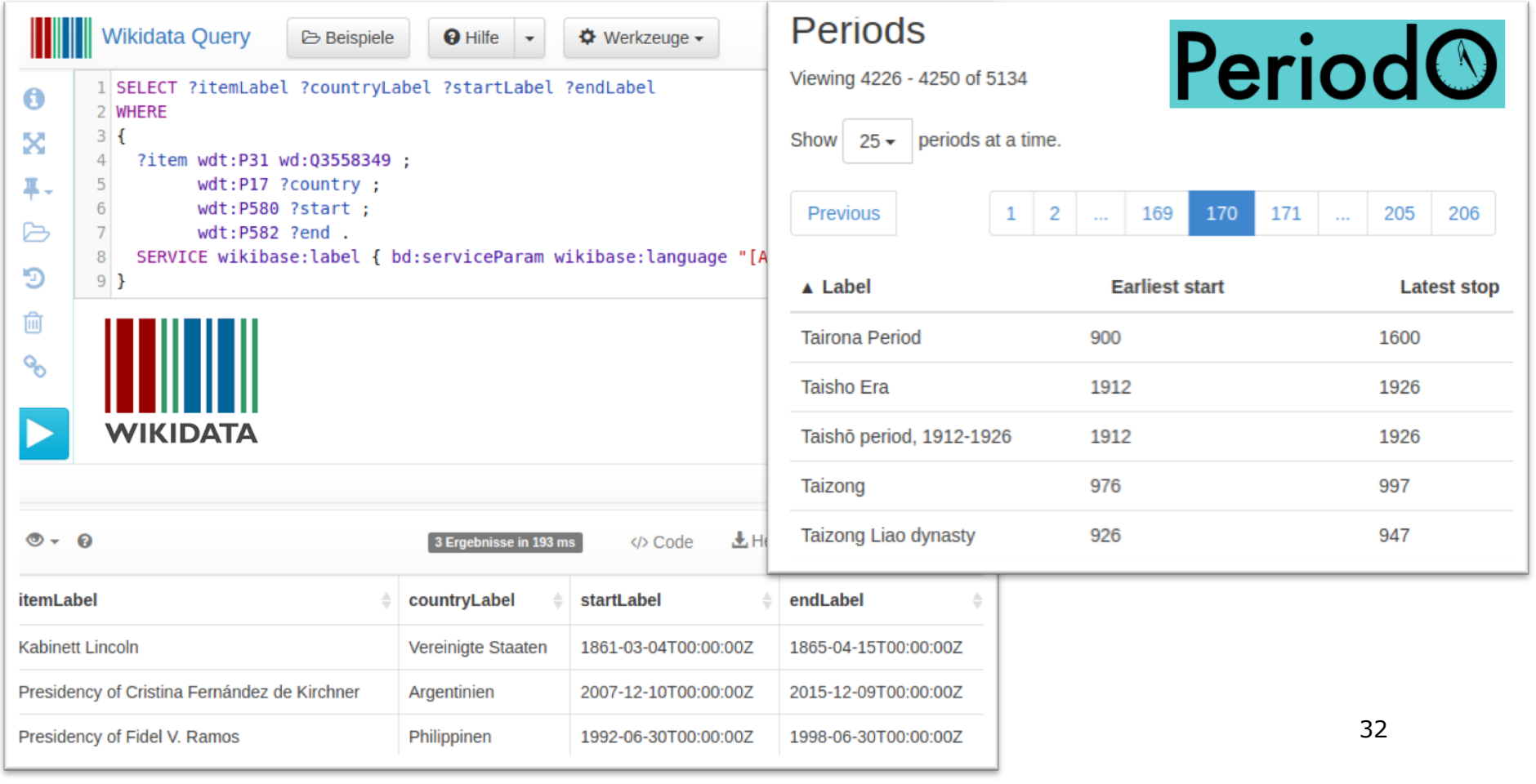
Extracting OSM streets and places



Wikidata, GeoNames

Wikidata links

Available Temporal Knowledge



Temporal Knowledge Graph Construction

WU WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

```
CONSTRUCT {
  ?event rdfs:label ?label ; dcterms:isPartOf ?Parent ; dcterms:coverage ?geocoordinates ;
    timex:hasStartTime ?StartDateTime ; timex:hasEndTime ?EndDateTime ; dcterms:spatial ?geoentity .
} WHERE {
  # find events with (for the moment) English, German, or non-language-specific labels:
  ?event wdt:P31/wdt:P279* wd:Q1190554 . ?event rdfs:label ?label .
  FILTER( LANG(?label) = "en" || LANG(?label) = "de" || LANG(?label) = "" ).
  # restrict to certain event categories, e.g. (for the moment) elections and sports events:
  {  # elections   #sports competitions
   { ?event wdt:P31/wdt:P279* wd:Q40231 } UNION { ?event wdt:P31/wdt:P279* wd:Q13406554 }
  }
  { # with a point in time or start end end date
    { ?event wdt:P585 ?StartDateTime . FILTER ( ?StartDateTime > "1900-01-01T00:00:00"^^xsd:dateTime) }
    UNION
    { ?event wdt:P580 ?StartDateTime. FILTER ( ?StartDateTime > "1900-01-01T00:00:00"^^xsd:dateTime)
      ?event wdt:P582 ?EndDateT. FILTER ( DATATYPE(?EndDateT) = xsd:dateTime) }
  }
  OPTIONAL { ?event wdt:P361 ?Parent }
  # specific spatialCoverage if available
  OPTIONAL { ?event wdt:P276?/(wdt:P17|wdt:P131) ?geoentity }
  OPTIONAL { ?event wdt:P276?/wdt:P625 ?geocoordinates }
  BIND ( if(bound(?EndDateT), ?EndDateT, xsd:dateTime(concat(str(xsd:date(?StartDateTime)),"T23:59:59"))) AS ?EndDateTime )
}
```

```
CONSTRUCT {
   ?P rdfs:label ?label ; dcterms:isPartOf ?Parent ; dcterms:spatial ?geo ;
   timex:hasStartTime ?StartDateTime ; timex:hasEndTime ?EndDateTime .
} WHERE {
  {
    { ?P skos:prefLabel ?label } UNION { ?P skos:altLabel ?label } UNION { ?P rdfs:label ?label }
  }
  ?P time:intervalFinishedBy ?End ; time:intervalStartedBy ?Start.
  OPTIONAL { ?P periodo:spatialCoverage ?geo }
  OPTIONAL { ?P dcterms:spatial ?geo }
  OPTIONAL { ?P dcterms:isPartOf ?Parent. }
  OPTIONAL{ ?End time:hasDateTimeDescription ?EndTime .
    OPTIONAL{ ?EndTime time:year ?EndYear }
    OPTIONAL{ ?EndTime periodo:latestYear ?EndYear }
  }
  OPTIONAL{ ?Start time:hasDateTimeDescription ?StartTime .
    OPTIONAL{ ?StartTime time:year ?StartYear }
    OPTIONAL{ ?StartTime periodo:earliestYear ?StartYear }
  }
  OPTIONAL{ ?Start (!periodo:aux)+ ?StartYear. FILTER (isLiteral(?StartYear)) }
  OPTIONAL{ ?End (!periodo:aux)+ ?EndYear. FILTER (isLiteral(?StartYear)) }

FILTER( ?StartYear >= "1900"^^xsd:gYear || xsd:integer(?StartYear) >= 1900 ||
        ?EndYear >= "1900"^^xsd:gYear || xsd:integer(?EndYear) >= 1900 )

  BIND( xsd:dateTime(concat(str(?StartYear),"-01-01T00:00:00")) as ?StartDateTime )
  BIND( xsd:dateTime(concat(str(?EndYear),"-12-31T23:59:59")) as ?EndDateTime ) }
```

- Named events and their labels
- Links to parent periods
- Temporal extent: a single beginning and end date
- Links to the spatial coverage

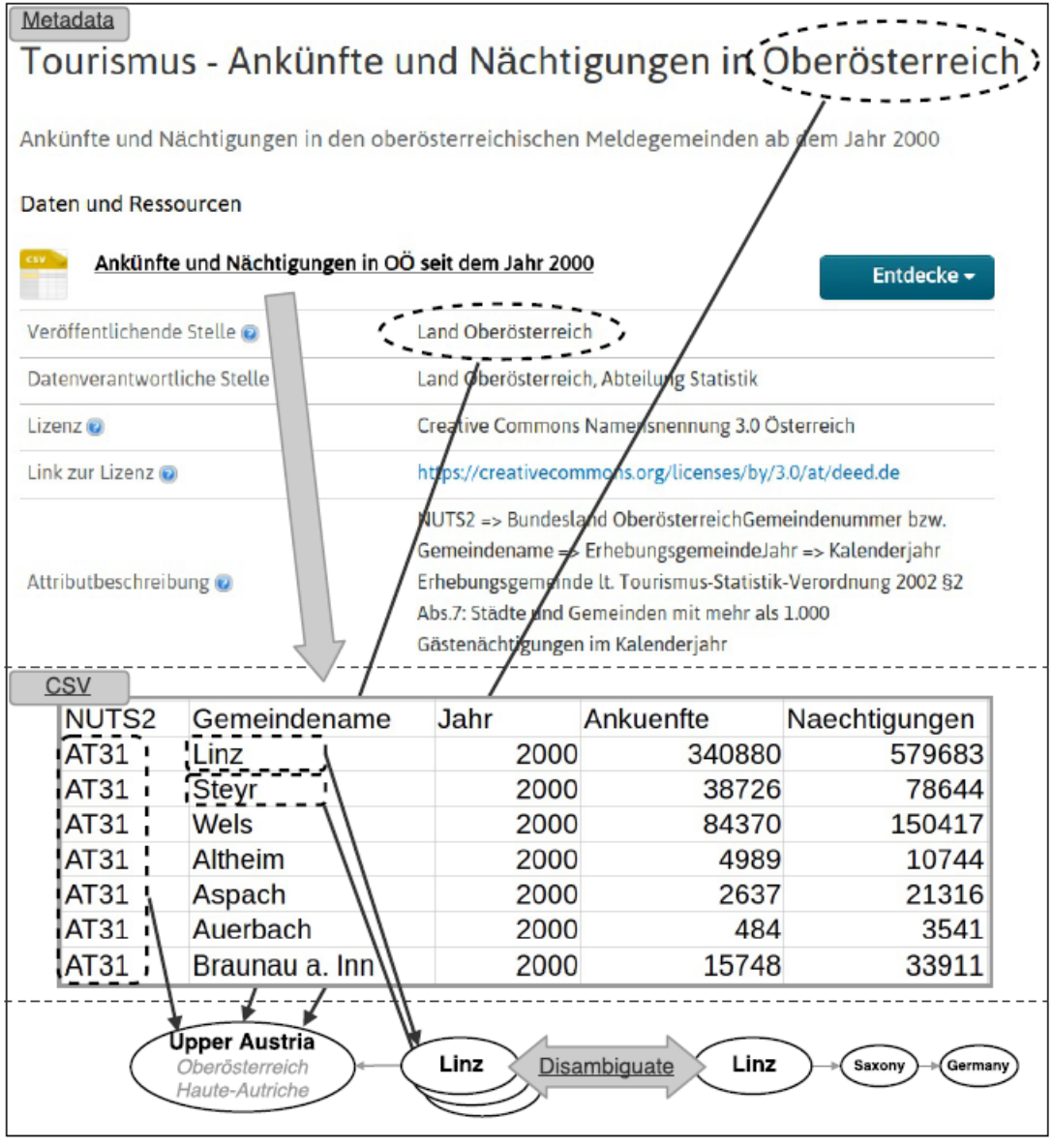
Dataset Labelling

Metadata descriptions

- Geo-entities in titles, descriptions, organizations
- Restricted to „origin" country of the dataset (from portal)
- Temporal tagging using Heideltime framework [3]

CSV cell value disambiguation

- Row context:
  - Filter candidates by potential parents (if available)
- Column context:
  - Least common ancestor of the spatial entities

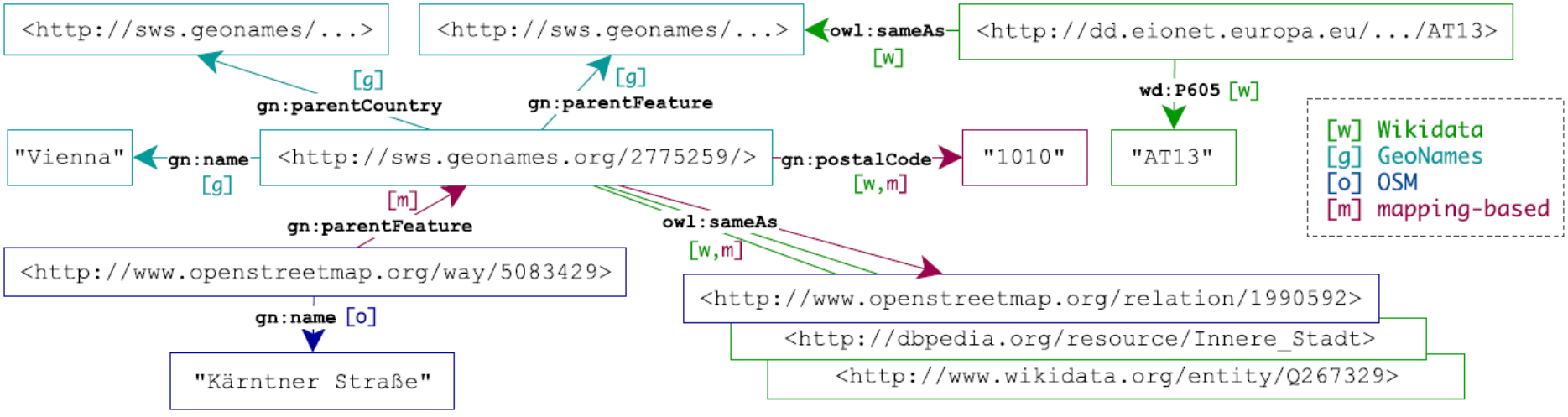


[3] Strötgen, Gertz: Multilingual and Cross-domain Temporal Tagging. Language Resources and Evaluation, 2013.

Indexed Datasets

portal	datasets	CSVs	indexed
total			15728
govdata.de	19464	10006	5646
data.gv.at	20799	18283	2791
offenedaten.de	28372	4961	2530
datos.gob.es	17132	8809	1275
data.gov.ie	6215	1194	884
data.overheid.nl	12283	1603	828
data.gov.uk	44513	7814	594
data.gov.gr	6648	414	496
data.gov.sk	1402	877	384
www.data.gouv.fr	28401	6038	258
opingogn.is	54	49	41

RDF Export 1/2: Knowledge Graph

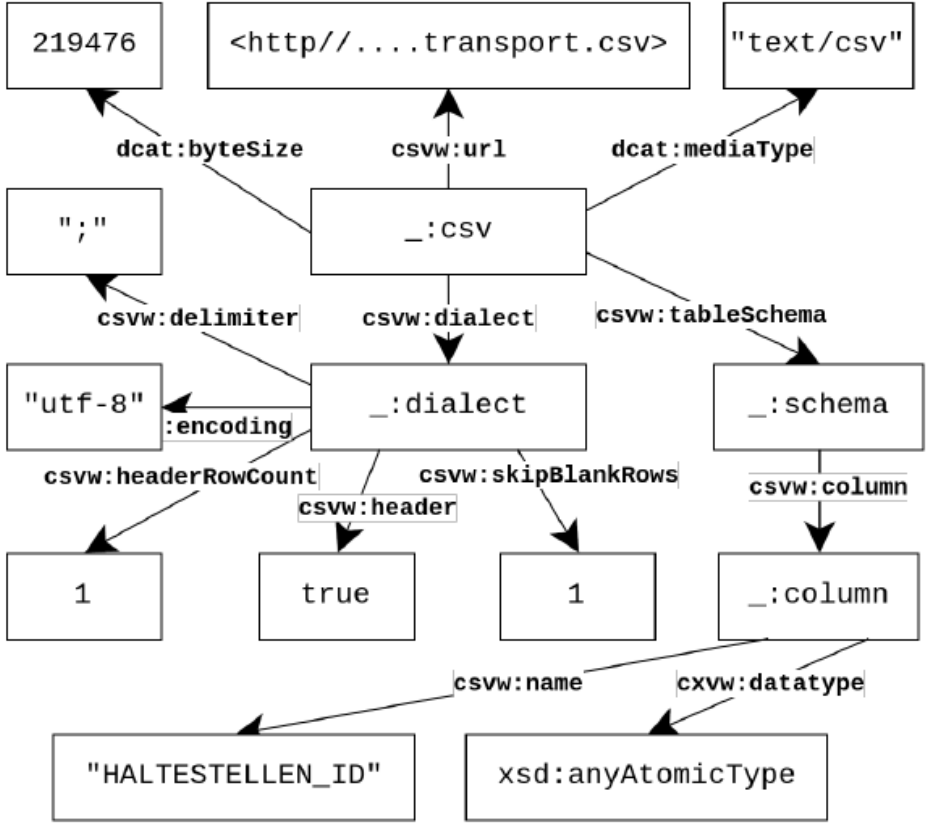


- Spatial and temporal base knowledge graph
- Annotated data points in metadata and CSV cells
- CSV metadata using CSVW vocabulary
  - e.g., delimiter, encoding, header, …

RDF Export 2/2: CSV on the Web Metadata [4]

- Note: no real cell level annotaitons, we needed to add those!
- E.g.:
  - csvwx:cell
    - csvwx:hasTime
    - csvw:refersToEntity
  - …

Details: cf.: http://data.wu.ac.at/ns/csvwx



[4] R. Pollock et al., Metadata Vocabulary for Tabular Data, W3C CSV on the Web (2015)

SPARQL Endpoint (1)

- Find datasets within time-range and referring to geospatial entity:

```
SELECT ?d ?url WHERE {
  # select the dates of the past two election in Austria
  wd:Q1386143 timex:hasStartTime ?t1 .
  wd:Q19311231 timex:hasStartTime ?t2 .

  # select the min and max date values of a dataset
  ?d dcat:distribution [
    dcat:accessURL ?url ;
    timex:hasStartTime ?start ;
    timex:hasEndTime ?end
  ] .
  # select only datasets about Vienna
  ?d csvwx:refersToEntity <http://sws.geonames.org/2761369/> .

  FILTER((?start >= ?t1) && (?end <= ?t2))
}
```

SPARQL Endpoint (2)

- Text search for a time period and its temporal and spatial coverage

- Query for cells within time period and referring to geo-entity

```
SELECT ?d ?url ?rownum WHERE {
  # get the "Anschluss movement"
  ?p rdfs:label ?L.
  FILTER (CONTAINS(?L, "Anschluss movement") ) .
  ?p timex:hasStartTime ?start ; timex:hasEndTime ?end ; dcterms:spatial ?sp .
  # find the GeoNames entities
  ?spatial owl:sameAs ?sp .
  ?d dcat:distribution [ dcat:accessURL ?url ] .
  [] csvw:url ?url ; csvw:tableSchema ?s .
  # find a cell where date falls in the range of the found period
  ?s csvw:column ?col1 .
  ?col1 csvwx:cell [
    csvw:rownum ?rownum ;
    csvwx:hasTime ?cTime
  ]
  FILTER((?cTime >= ?start) && (?cTime <= ?end))
  # find another cell in the same row where the geo-entity has the
  # spatial coverage area of the found period as the parent country
  ?s csvw:column ?col2 .
  ?col2 csvwx:cell [
    csvw:rownum ?rownum ;
    csvwx:refersToEntity [ gn:parentCountry ?spatial ]
  ]
}
```

GeoSPARQL Queries

- Standard for representation and querying of geospatial linked data
- (Almost) no complete implementations of GeoSPARQL

```
SELECT ?d ?url ?rownum WHERE {
  # get the geometry of the Viennese district "Leopoldstadt"
  <http://sws.geonames.org/2772614/> geosparql:hasGeometry ?polygon .

  ?d dcat:distribution [ dcat:accessURL ?url ] .
  [ csvw:url ?url ; csvw:tableSchema ?s ].
  # select the geometries of any annotated cells
  ?s csvw:column ?col .
  ?col csvwx:cell [ csvw:rownum ?rownum ; csvwx:refersToEntity [ geosparql:hasGeometry ?g ]

  # filter all annotated data points within the polygon of Leopoldstadt
  FILTER(geof:sfWithin(?g, ?polygon))
}
```

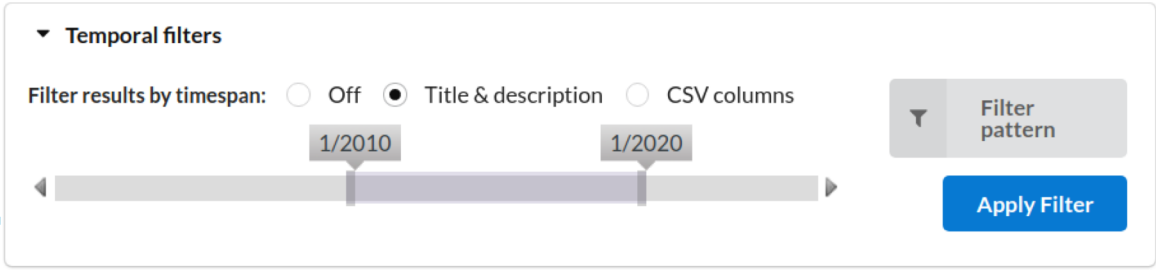
Search Interface

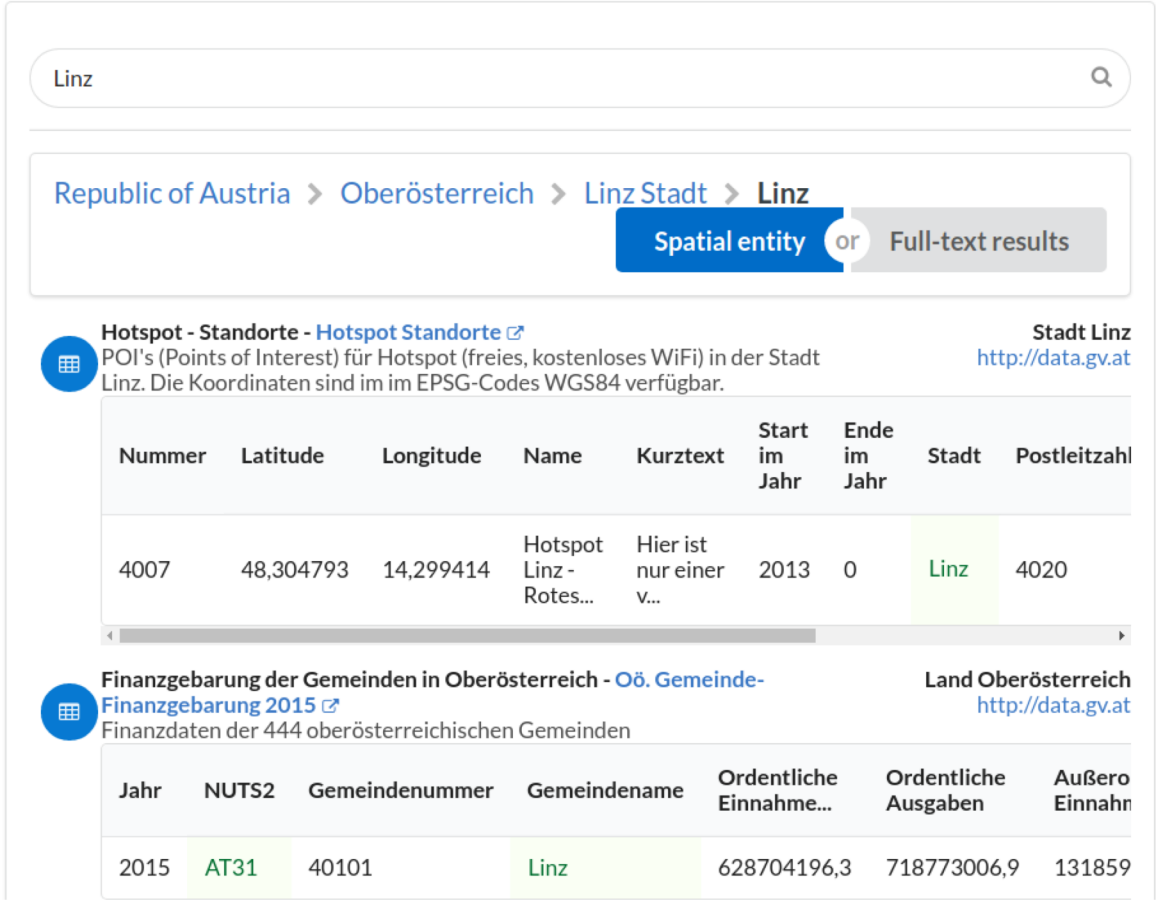
Faceted query interface:

- Timespan
- Time pattern
- Geo-entities
- Full-text queries

Back end:

- **MongoDB** for efficient key look-ups
- **ElasticSearch** for indexing and full-text queries
- **Virtuoso** as a triple store





Conclusions & Outlook

- Open (Structured) Data is a rich source of Knowledge worthwhile to tap into
- Most of it is not (yet) Linked Data.

What we did:

- Hierarchical knowledge graph of spatial and temporal entities
- Algorithms to annotate CSV tables and their metadata descriptions
  → KGs improve search (with some extra work)

What's next:

- Enable GeoSPARQL (or an alternative geospatial-query language)
- Parsing coordinates in datasets
- Extending the base KG/Linking more entities:
  - Publishing organisations, governance, elections, etc.
- Parse other file fomats, e.g., XML, PDF, …
- Use our enrichments to link Open data with other data: tweets or web pages (e.g., newspaper articles)

Other Ongoing Projects (data.wu.ac.at)

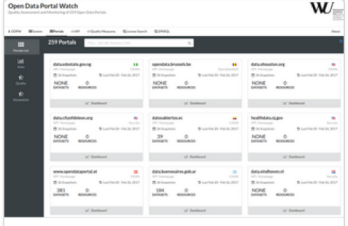
Projects

WU Open Data Portal

WU lectures, rooms and organizations

data.wu.ac.at is an Open Data portal where you can find data about lectures, rooms and organizations at WU.

121 datasets

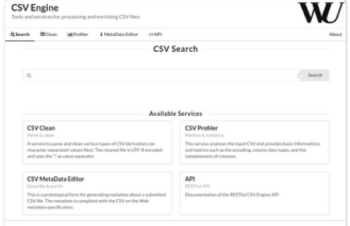


Open Data Portal Watch

Monitoring & exposing portals' metadata

Open Data Portal Watch assesses the evolution of the (meta) data quality of about 260 Open Data portals over since September 2014.

259 portals



CSV Engine

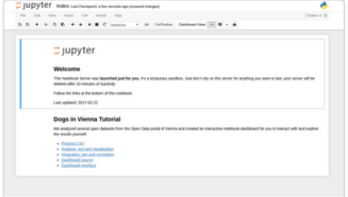
Search & enrich CSVs

The CSV Engine is a collection of tools and services for processing and enriching CSV files.

DBpedia Wayback Machine

Extract past DBpedia versions

The DBpedia Wayback Machine aims at providing the wayback functionality for DBpedia based on the revisions of their Wikipedia article.



Jupyter Notebook Server

Programming & Documentation

Notebook documents are documents which contain both computer code (e.g. python) and human-readable rich text elements.

Only available within local WU Vienna network

Open Data AT Assistant

Search chatbot for Austrian datasets

The assistant will help you to explore the content of the austrian open data portals: data.gv.at and opendataportal.at.

What else are we working on?

- Open Data Portalwatch
  - 1) Monitoring Metadata quality
  - 2) Mapping to standard vocabularies
  - 3) Enriching Metadata to improve search (*talked about that already*)

1) Monitoring and QA over evolving data portals

3/2015 [1]:
- 90 portals
- Only **CKAN**

8/2015 [2]:
- 6 **quality metrics**
- QA

6/2016 [3]:
- 260 portals
- CKAN, **Socrata**, **OpenDataSoft**
- 18 metrics

	total	CKAN	Socrata	ODSoft	DCAT
portals	261	149	99	11	2
datasets	854,013	767,364	81,268	3,340	2,041
URLs	2,057,924	1,964,971	104,298	12,398	6,092

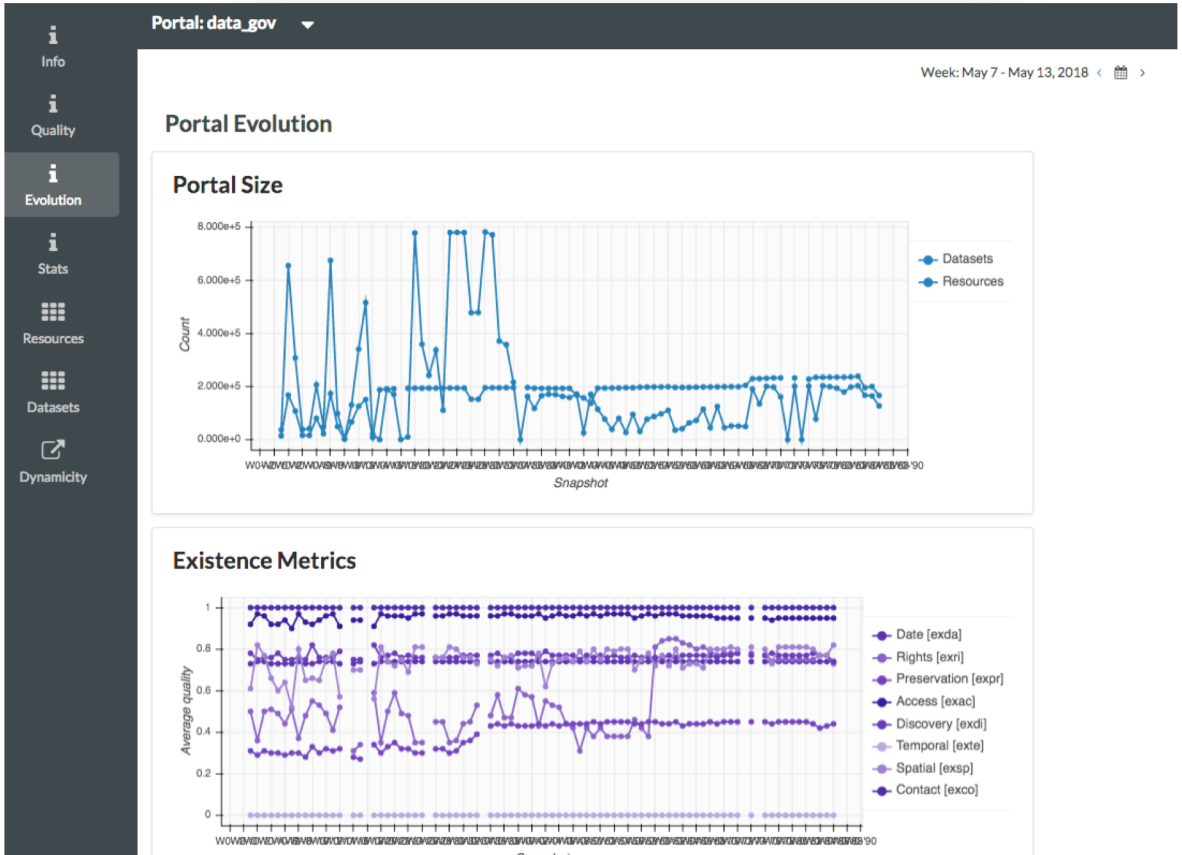
[1] Towards assessing the quality evolution of open data portals. In ODQ2015: Open Data Quality Workshop, Munich, Germany

[2] Quality assessment & evolution of open data portals. In: International Conference on Open and Big Data, Rome, Italy (2015)

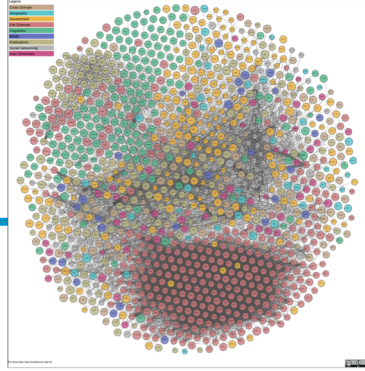
[3] Automated quality assessment of metadata across open data portals. ACM Journal of Data and Information Quality (2016)

Demo:

http://data.wu.ac.at/portalwatch/portal/data_gov/1818



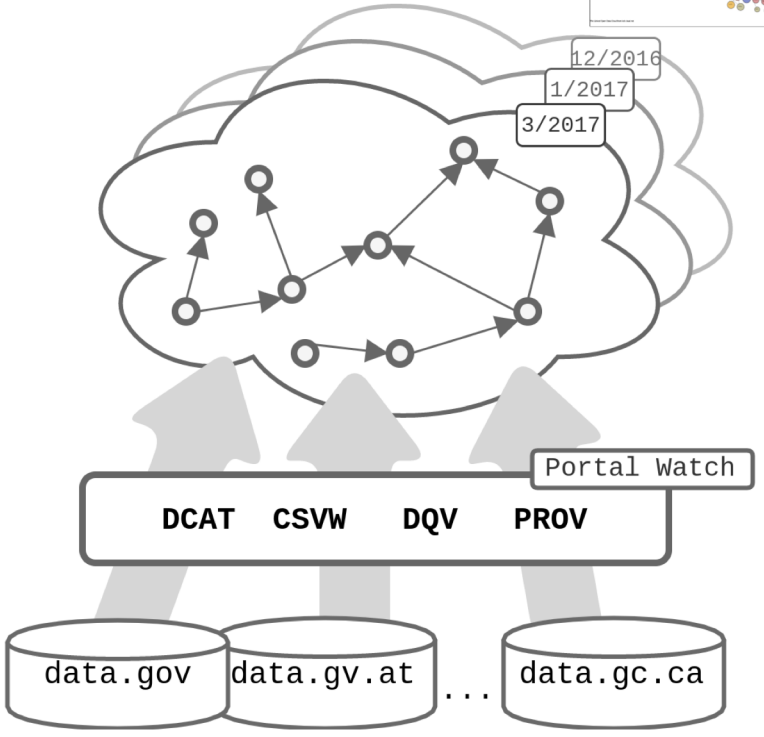
2) Mapping to Standard vocabularies & Linked Data



- Mapping & Heuristic Enrichment
  - DCAT
  - PROV
  - CSVW
  - Schema.org
- Enable uniform access:

  →SPARQL endpoint

  → Linked Data & Memento Protocol

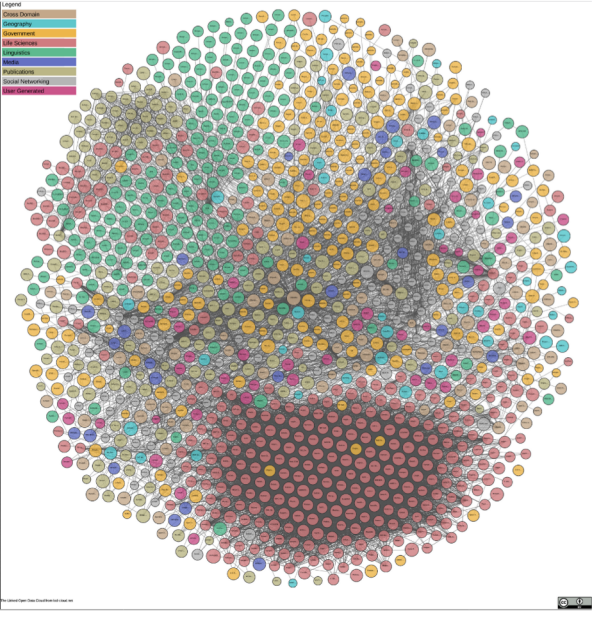


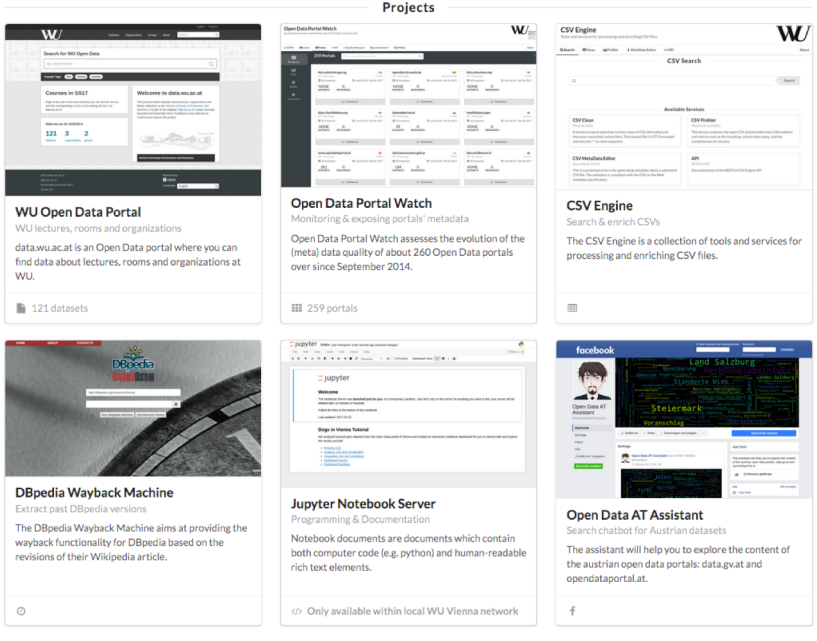
[1] http://data.wu.ac.at/portalwatch/sparql

[2] http://data.wu.ac.at/odso/

Thank you!

WU WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS





PRIVACY & SUSTAINABLE COMPUTING LAB

COMPLEXITY SCIENCE HUB VIENNA

Backup Slides

Spatio-temporal labelling – Evaluation:

Total numbers of spatial and temporal annotations of metadata descriptions and columns:

	Spatial	*Temporal*	
Columns	**Metadata**	**Columns**	**Metadata**
3518	11231	2822	9112

10 random CSV datasets per portal (11 portals), 10 random rows per dataset:

- In total inspected 101 datasets 1010 rows

- 87 Correctly assigned labels at the dataset level
- 37 CSV datasets that contain potentially missing annotations (e.g. text that would need to be parsed first, or malformed CSVs, etc.)
- 9 Incorrect links to GeoNames
- 9 Incorrect links to OSM