

A decorative background featuring a network graph with nodes and edges. The nodes are represented by circles of varying sizes and colors (blue, grey, white), connected by thin lines. The graph is partially visible on the left and right sides of the slide, framing the central text.

Multilinguality in Knowledge Graphs

Lucie-Aimée Kaffee

About Lucie



- Postdoc at University of Copenhagen (CopeNLU)
- PhD from University of Southampton (2020) as Marie-Curie ITN research fellow
- Research fellow at TIB Hannover (2019)
- Research internship at Bloomberg L.P. (2019/20)
- Software Developer at Wikimedia Deutschland in the Wikidata team (2014-2016)

About Lucie

Research Interests



- Multilingual Data
- Wikidata & Wikipedia
- Languages and Labels in Knowledge Graphs (this presentation)
- Natural Language Processing (NLP), with focus on application for KGs and integrating social science knowledge

Structure of the presentation

- Motivation
- Research Questions and respective studies/results
- Outlook on current work



Knowledge Graphs and Multilingual Data

Motivation

- A large number of applications serve multilingual users, e.g. question answering systems



Amazon Alexa, Image: CC-BY Pixabay



Google Home, Image: CC-BY-SA
[Wikimedia Commons](https://commons.wikimedia.org/wiki/File:Google_Home.jpg)

The screenshot displays a Bloomberg Terminal interface with multiple data windows. The top window shows 'China Onshore FI Overview' with a table of yields and benchmarks. The middle window shows 'GRAB Financial Analysis' with a table of financial metrics. The bottom window shows 'China Bond News' with a list of news items and function links.

Govt Benchmark	Yield	Last Yield	Last	Current	Chg	Last	Chg
1Y	3.4515	3.451	99.874	CNY	6.8880	0.0014	
3Y	3.6249	3.6008	97.9068	FX			
5Y	3.6787	3.679	97.577	CNH	6.8792	0.0036	
7Y	3.7565	3.757	96.694	Eq Indices			
10Y	3.6404	3.640	98.025	Shg	3110.596	-2.368	
CDR Benchmark				CSI300	3418.66	9.99	
1Y	4.0039	4.004	99.343	HSI	25268.11	-67.83	
3Y	4.3289	4.329	96.199	Economics			
5Y	4.4677	4.468	95.786	GDP	6.9	0.1	
				MthGDP	7.15		
				PIIYoY	81	0.3	
				Food	-2.83		
				Energy	476.700	-1.2	

	FY 2013	FY 2014	FY 2015	FY 2016	Current/TM	FY 2017 Est.	FY 2018 Est.
Revenue, Adj.	7,393.0	7,736.5	7,715.0	7,553.7	7,232.4	7,355.5	7,626.8
Gross Profit, Adj.	59.9	59.9	59.9	59.9	59.9	59.9	59.9
Operating Profit, Adj.	1,883.2	2,097.7	2,187.8	2,213.7	2,114.6	2,009.9	2,136.9
Net Income, Adj.	550.3	636.2	688.4	695.2	600.0	565.9	633.2
EPS, Adj.	-166.15	93.07	102.48	105.41	111.42	68.21	83.61
Free Cash Flow	18.6	380.2	267.3	156.8	18.3	68.8	105.0

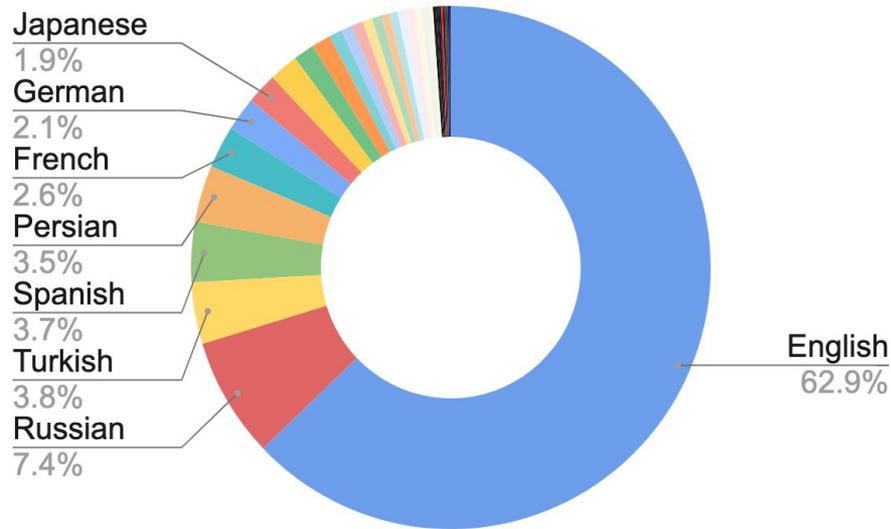
Bloomberg Terminal, Image Credits: [Bloomberg L.P.](https://www.bloomberg.com)

Motivation

- A large number of applications serve multilingual users, e.g. question answering systems
- However, a large number of users is not supported in their (native) language due to a lack of multilingual data

Motivation

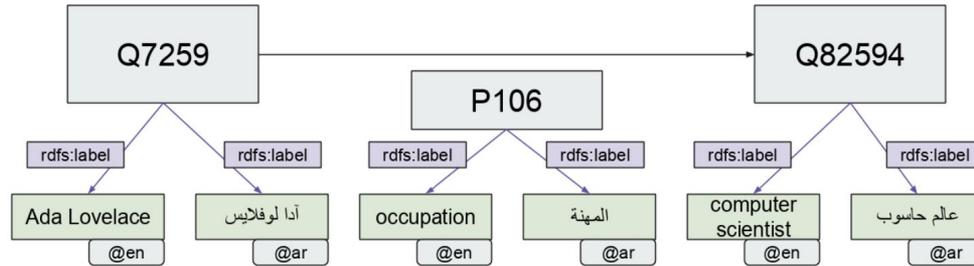
- Lack of language coverage on the web overall



Source: https://w3techs.com/technologies/overview/content_language

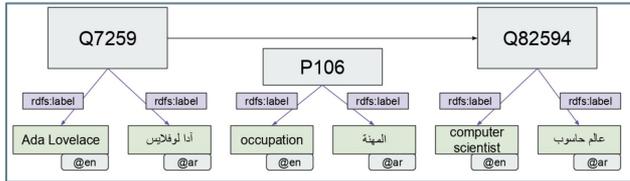
Motivation

- Knowledge graphs support a multilingual representation of concepts



Motivation

- Knowledge graphs could support a larger coverage of languages through, e.g., text generation



WIKIPEDIA The Free Encyclopedia

Ada Lovelace

From Wikipedia, the free encyclopedia

Augusta Ada King, Countess of Lovelace (*née* **Byron**; 10 December 1815 – 27 November 1852) was an English mathematician and writer, chiefly known for her work on Charles Babbage's proposed mechanical general-purpose computer, the *Analytical Engine*. She was the first to recognise that the machine had applications beyond pure calculation, and to have published the first *algorithm* intended to be carried out by such a machine. As a result, she is often regarded as the first computer programmer.^{[2][3]}

Ada Byron was the only child of poet Lord Byron and mathematician Lady Byron.^[4] All of Byron's other children were born out of wedlock to other women.^[5] Byron separated from his wife a month after Ada was born and left England forever four months later. He commemorated the parting in a poem that begins, "Is thy face like thy mother's my fair child! ADA! sole daughter of my house and heart?".^[7] He died in Greece when Ada was eight years old. Her mother remained bitter and promoted Ada's interest in mathematics and logic in an effort to prevent her from developing her father's perceived insanity. Despite this, Ada remained interested in him, naming her two sons Byron and Gordon. Upon her death, she was buried next to him at her request. Although often ill in her childhood, Ada pursued her studies assiduously. She married William King in 1835. King was made *Earl of Lovelace* in 1838, Ada thereby becoming *Countess of Lovelace*.

Her educational and social exploits brought her into contact with scientists such as Andrew Crosse, Charles Babbage, Sir David Brewster, Charles Wheatstone, Michael Faraday and the author Charles Dickens, contacts which she used to further her education. Ada described her approach as "poetical science"^[8] and herself as an "Analyst (& Metaphysician)".^[9]

When she was a teenager (18), her mathematical talents led her to a long working relationship and friendship with fellow British mathematician Charles Babbage, who is known as "the father of computers". She was in particular interested in Babbage's work on the Analytical Engine. Lovelace first met him in June 1833, through their mutual friend, and her private tutor, Mary Somerville.

Between 1842 and 1843, Ada translated an article by Italian military engineer Luigi Menabrea about the calculating engine, supplementing it with an elaborate set of notes, simply called "Notes". Lovelace's notes are important in the early history of computers, containing what many consider to be

The Right Honourable
The Countess of Lovelace

Daguerrotype by Antoine Claudet (c. 1843)^[1]

Born The Hon. Augusta Ada Byron
10 December 1815
London, England



How can we support multilingual access to knowledge graphs for speakers of low-resourced languages?

RQ1 What is the state of knowledge graphs with regard to labels and multilinguality?

RQ2 Does knowledge about languages in a knowledge graph support ranking them for question answering?

RQ3 Can we automatically translate knowledge graph labels and aliases?

RQ4 Can we reuse Wikidata's multilingual data to generate Wikipedia summaries?



RQ1 What is the state of knowledge graphs with regard to labels and multilinguality?



Pavlos Vougiouklis, Huawei
Alessandro Piscopo, BBC

RQ2 Does knowledge about languages in a knowledge graph support ranking them for question answering?

Kemele M. Endris, Amazon



TIB
LEIBNIZ INFORMATION CENTRE
FOR SCIENCE AND TECHNOLOGY
UNIVERSITY LIBRARY

RQ3 Can we automatically translate knowledge graph labels and aliases?

Bloomberg

RQ4 Can we reuse Wikidata's multilingual data to generate Wikipedia summaries?



Hady Elsahar, Meta
Pavlos Vougiouklis, Huawei

How can we support multilingual access to knowledge graphs for speakers of low-resourced languages?

RQ1 What is the state of knowledge graphs with regard to labels and multilinguality?

Kaffee and Simperl: The Human Face of the Web of Data: A Cross-sectional Study of Labels [SEMANTiCS 2018]; Kaffee et al.: When Humans and Machines Collaborate: Cross-lingual Label Editing in Wikidata [OpenSym 2019]; Kaffee et al.: A glimpse into Babel: an analysis of multilinguality in Wikidata [OpenSym 2017]; Kaffee and Simperl: Analysis of Editors' Languages in Wikidata [OpenSym 2018]

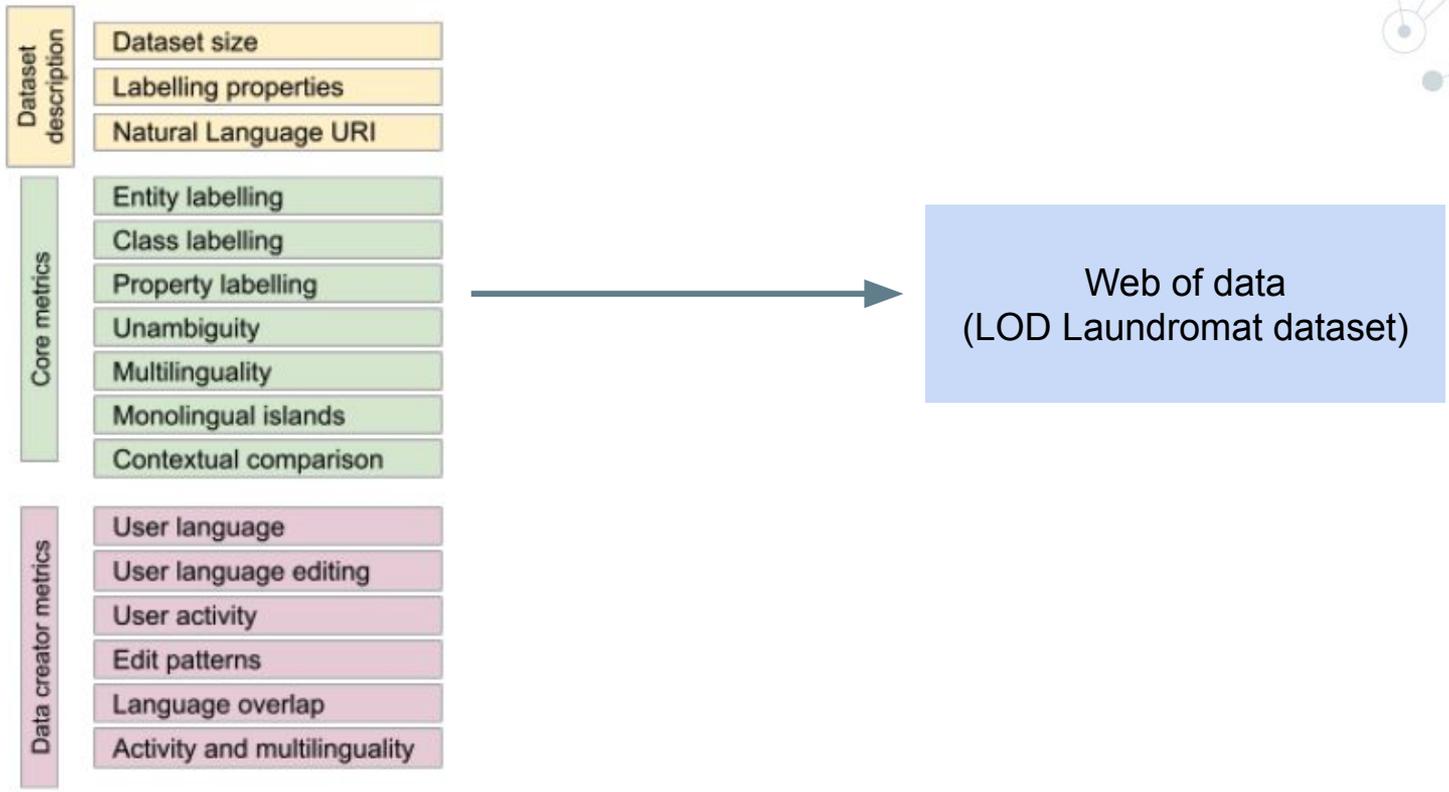
Framework to measure multilinguality in KGs

Dataset description
Dataset size
Natural language URI
Labelling properties

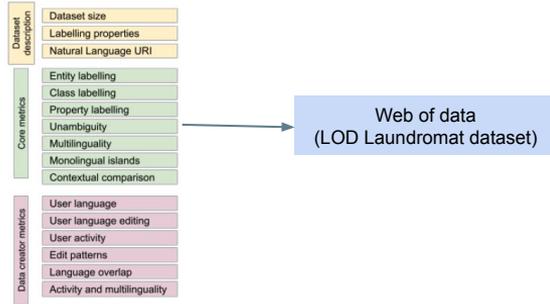
Core metrics
Entity label completeness
Class label completeness
Property label completeness
Unambiguity
Multilinguality
Monolingual Islands
Contextual comparison

Data creator metrics
User language
User language editing
User activity
Edit patterns
Language overlap
Activity and Multilinguality

Framework to measure multilinguality in KGs



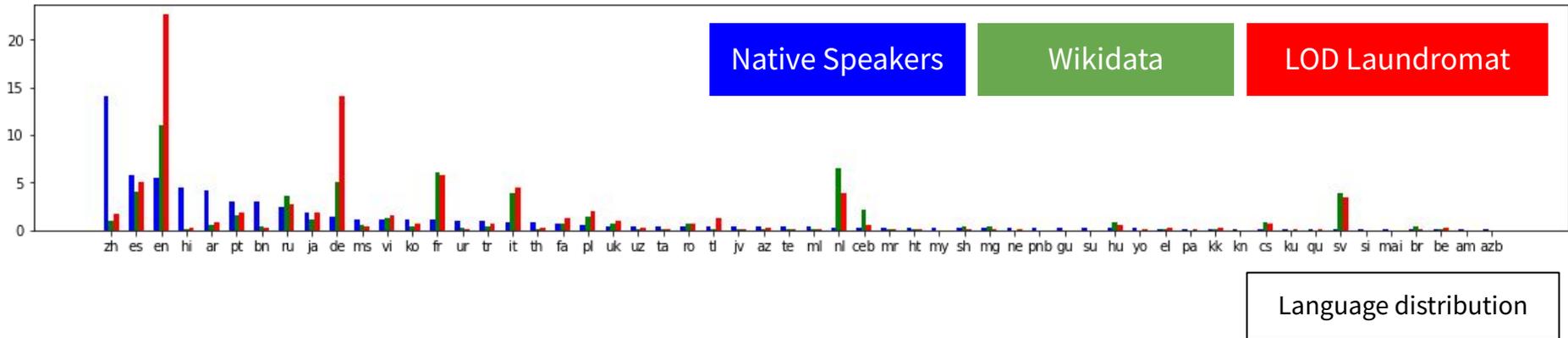
Framework to measure multilinguality in KGs



- **rdfs:label** is by far the most used labelling property
- Only **5.42%** of subjects are **labelled**, **80.9%** of properties are labelled
- The **five** most used **languages** cover **over 50%** of labels
- **83.2%** of entities are labelled in only **one language**

Multilinguality in Wikidata

- Compared to the Web of data at large, Wikidata's editors create a more diverse knowledge graph



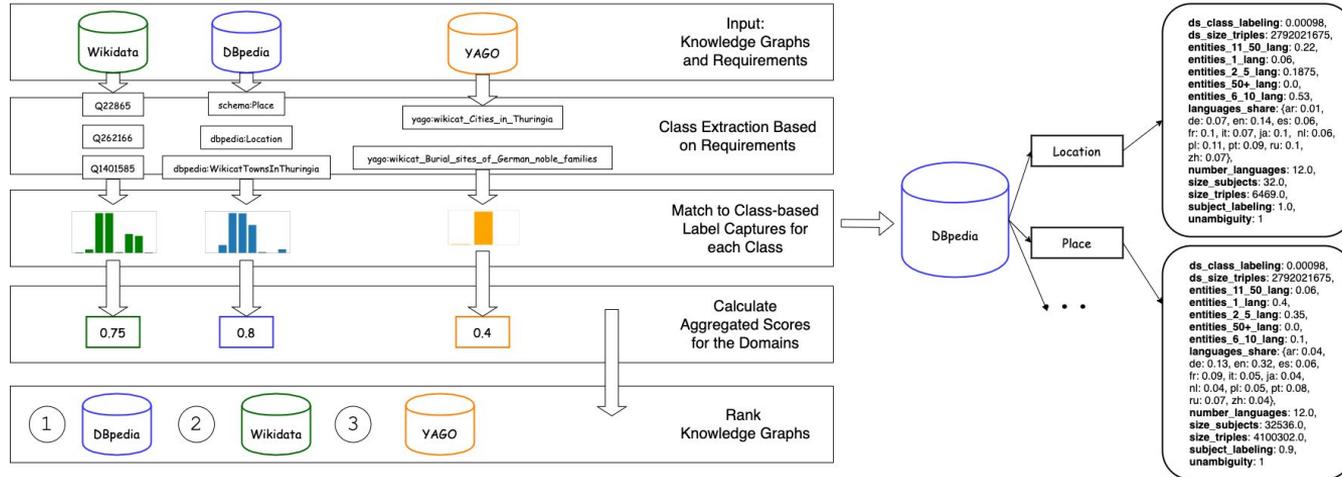


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LINGVO, framework to rank KGs based on labels and languages



1

Where was Bach born?

English

2

```

db:Bach dbo:birthPlace db:Germany
db:Bach rdfs:label "Johann Sebastian Bach"@en
db:Germany rdfs:label "Germany"@en
db:Germany rdfs:label "BRD"@en
db:Germany rdfs:label "Deutschland"@de
db:birthPlace rdfs:label "birth place"@en

```

Knowledge Graph 1 (KG1)

Wo wurde Bach geboren?

German

```

wd:Q255 wd:P19 wd:Q183
wd:Q183 rdfs:label "Germany"@en
wd:Q183 rdfs:label "Deutschland"@de
wd:Q183 rdfs:label "Almanya"@tr
wd:Q255 rdfs:label "Johann Sebastian Bach"@en
wd:Q255 rdfs:label "Johann Sebastian Bach"@de
wd:P19 rdfs:label "Geburtsort"@de
wd:P19 rdfs:label "birth place"@en

```

Knowledge Graph 2 (KG2)

¿Dónde nació Bach?

Spanish

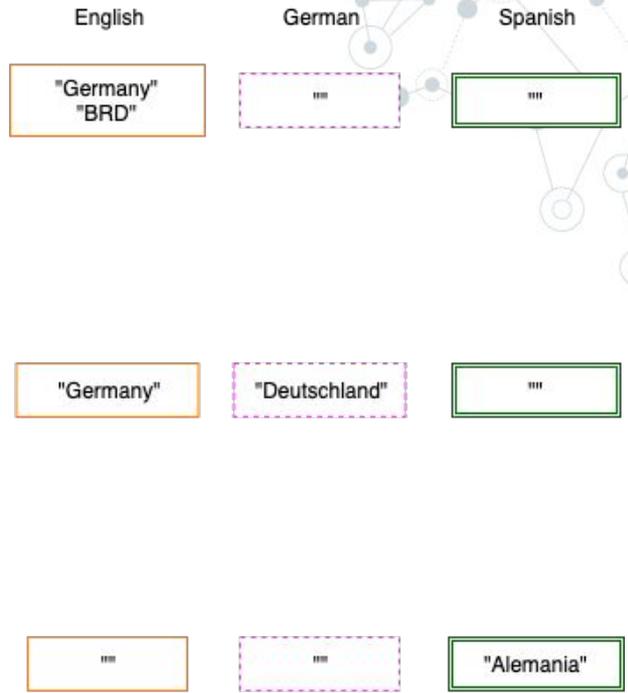
```

ex:12 ex:31 ex:13
ex:12 rdfs:label "Johann Sebastian Bach"@es
ex:31 rdfs:label "lugar de nacimiento"@es
ex:13 rdfs:label "Alemania"@es
ex:12 rdfs:label "Allemagne"

```

Knowledge Graph 3 (KG3)

3



1

Select a Knowledge Graph

3

Where was Bach born?

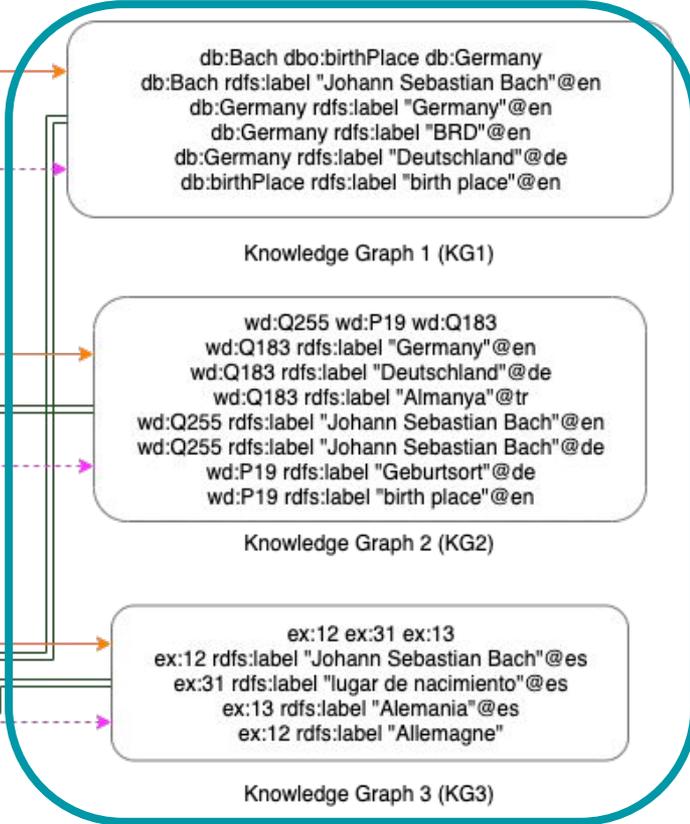
English

Wo wurde Bach geboren?

German

¿Dónde nació Bach?

Spanish



English
"Germany"
"BRD"

German
""

Spanish
""

"Germany"

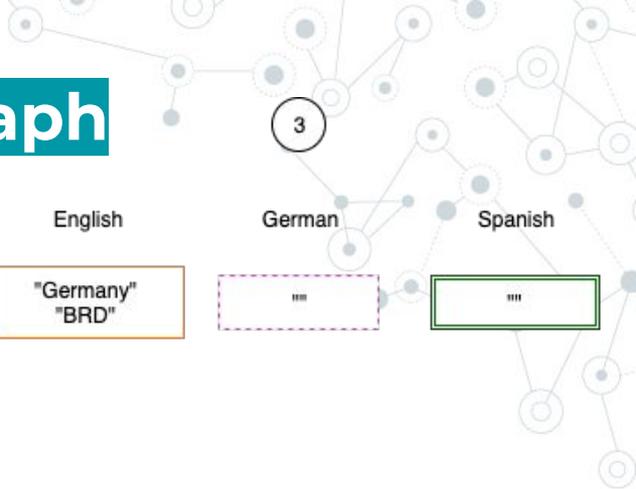
"Deutschland"

""

""

""

"Alemania"



1

That answers the question best

Where was Bach born?

English

Wo wurde Bach geboren?

German

¿Dónde nació Bach?

Spanish

```

db:Bach dbo:birthPlace db:Germany
db:Bach rdfs:label "Johann Sebastian Bach"@en
db:Germany rdfs:label "Germany"@en
db:Germany rdfs:label "BRD"@en
db:Germany rdfs:label "Deutschland"@de
db:birthPlace rdfs:label "birth place"@en

```

Knowledge Graph 1 (KG1)

```

wd:Q255 wd:P19 wd:Q183
wd:Q183 rdfs:label "Germany"@en
wd:Q183 rdfs:label "Deutschland"@de
wd:Q183 rdfs:label "Almanya"@tr
wd:Q255 rdfs:label "Johann Sebastian Bach"@en
wd:Q255 rdfs:label "Johann Sebastian Bach"@de
wd:P19 rdfs:label "Geburtsort"@de
wd:P19 rdfs:label "birth place"@en

```

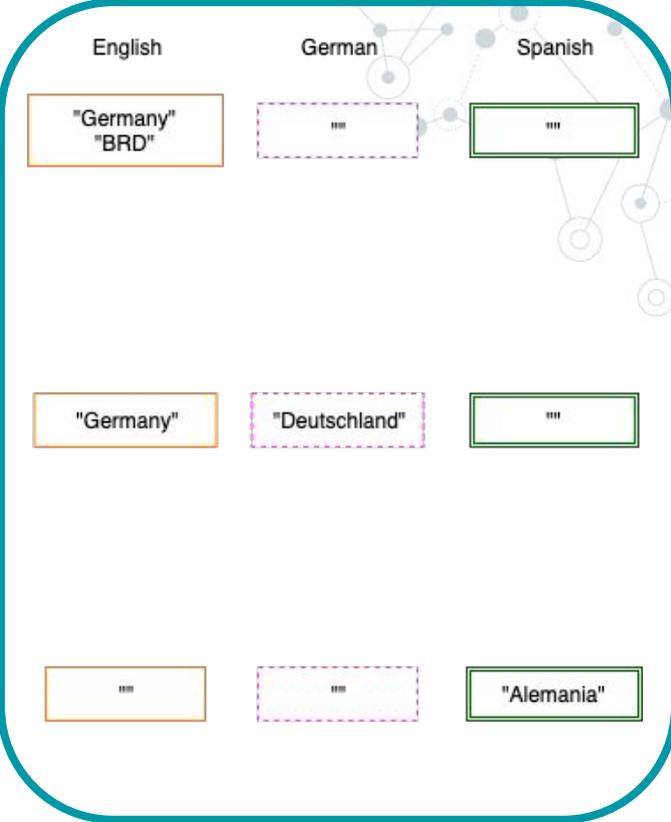
Knowledge Graph 2 (KG2)

```

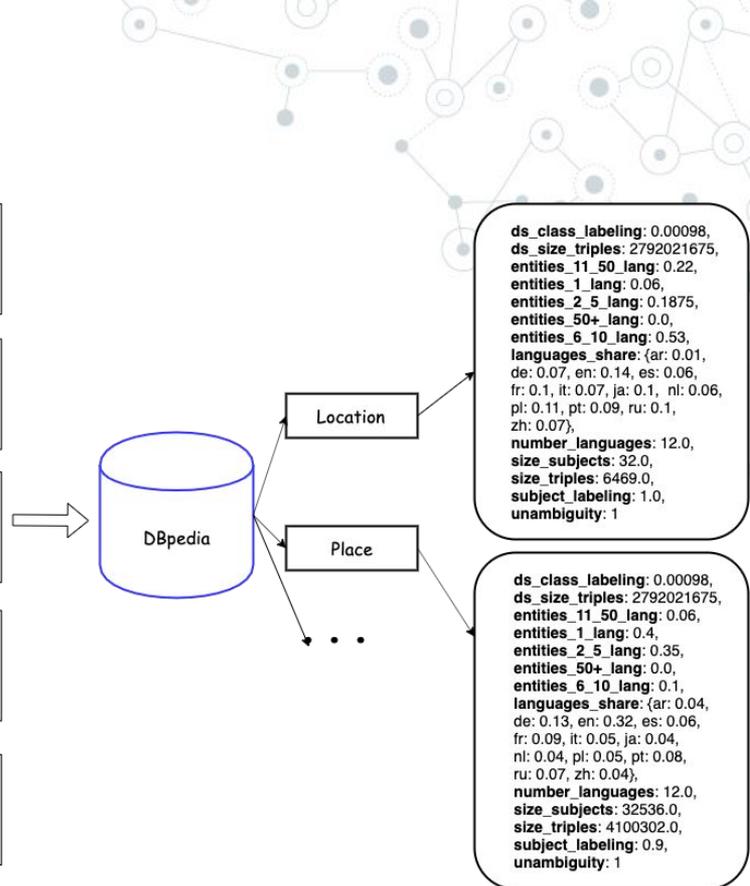
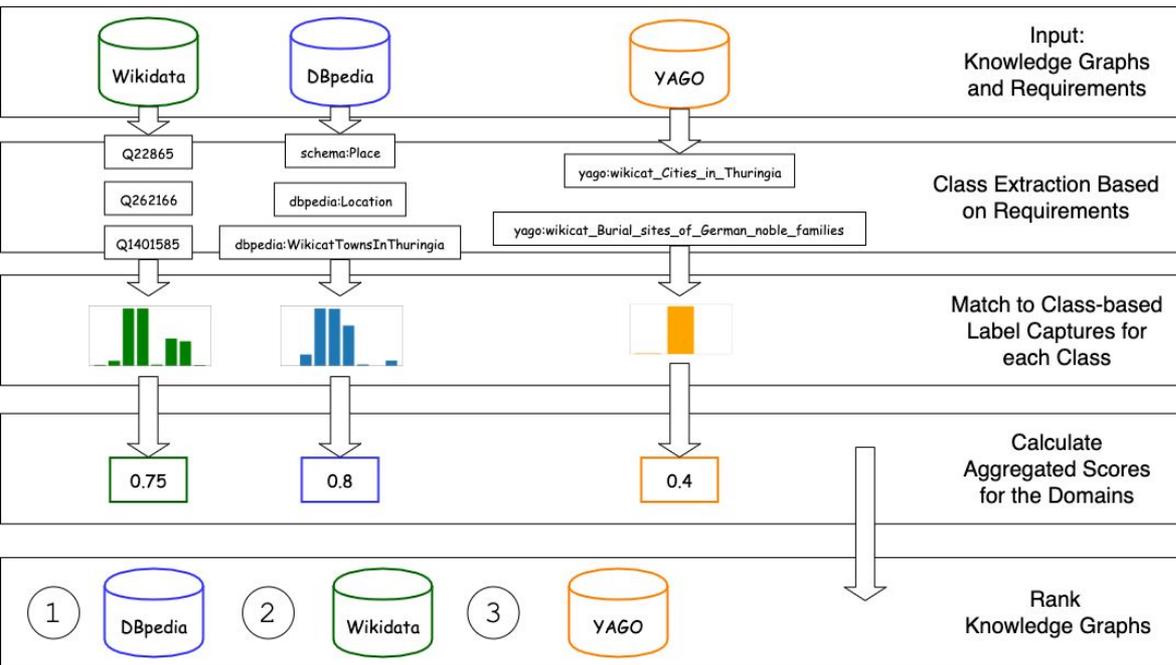
ex:12 ex:31 ex:13
ex:12 rdfs:label "Johann Sebastian Bach"@es
ex:31 rdfs:label "lugar de nacimiento"@es
ex:13 rdfs:label "Alemania"@es
ex:12 rdfs:label "Allemagne"

```

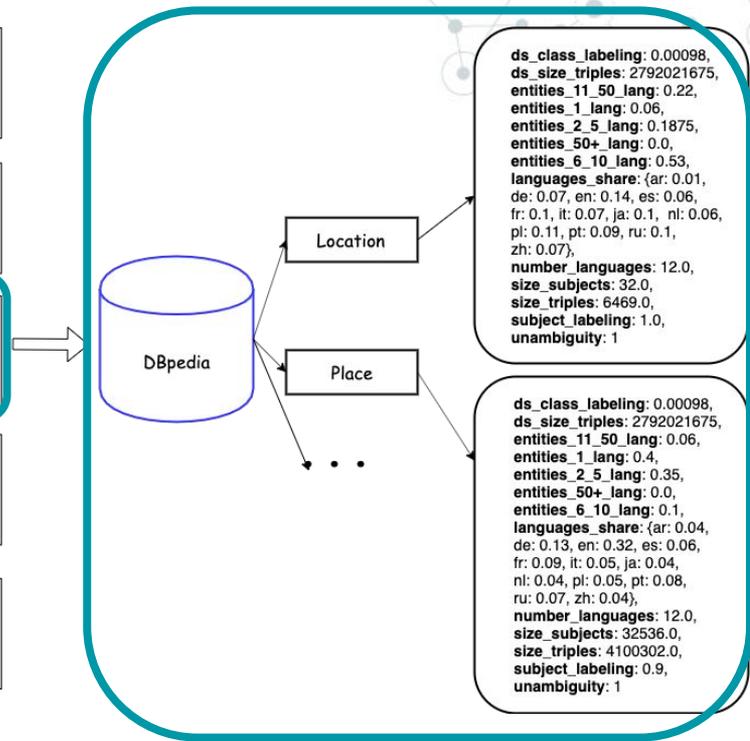
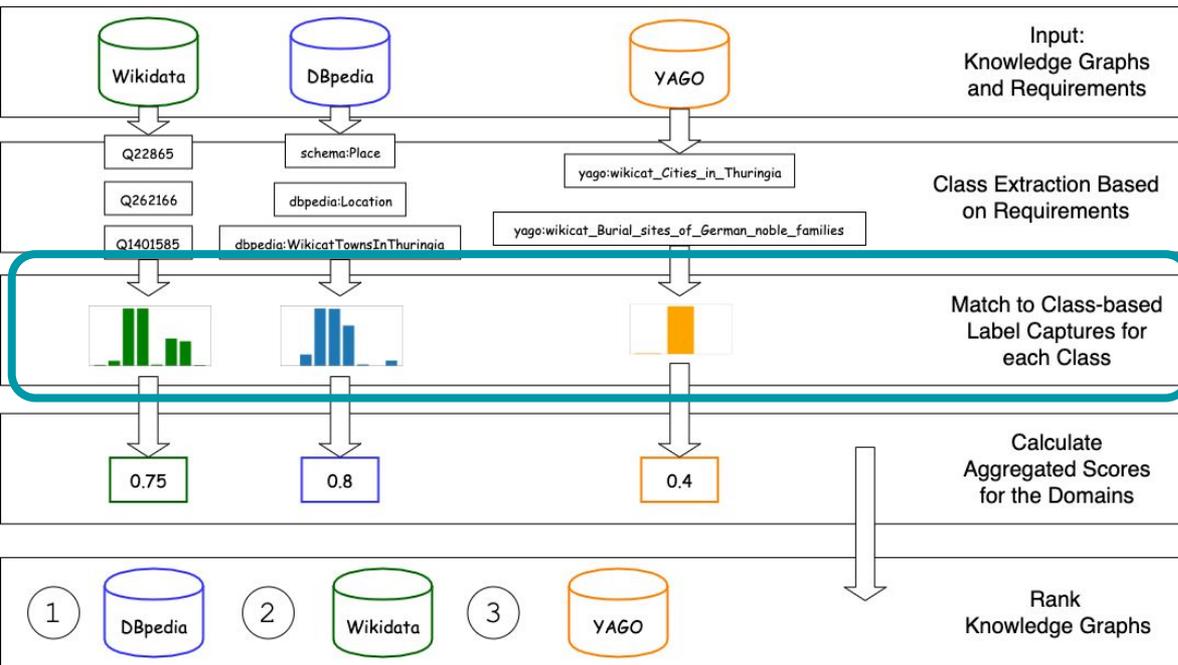
Knowledge Graph 3 (KG3)



Rank Knowledge Graphs

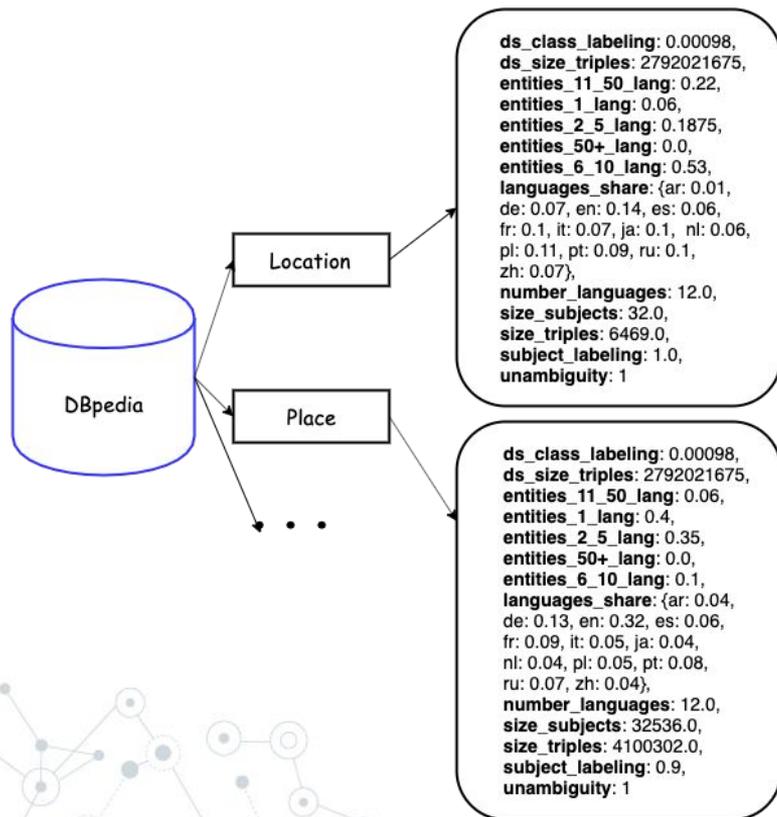


Rank Knowledge Graphs



Based on the framework

Class-based Label Capture (CLC)

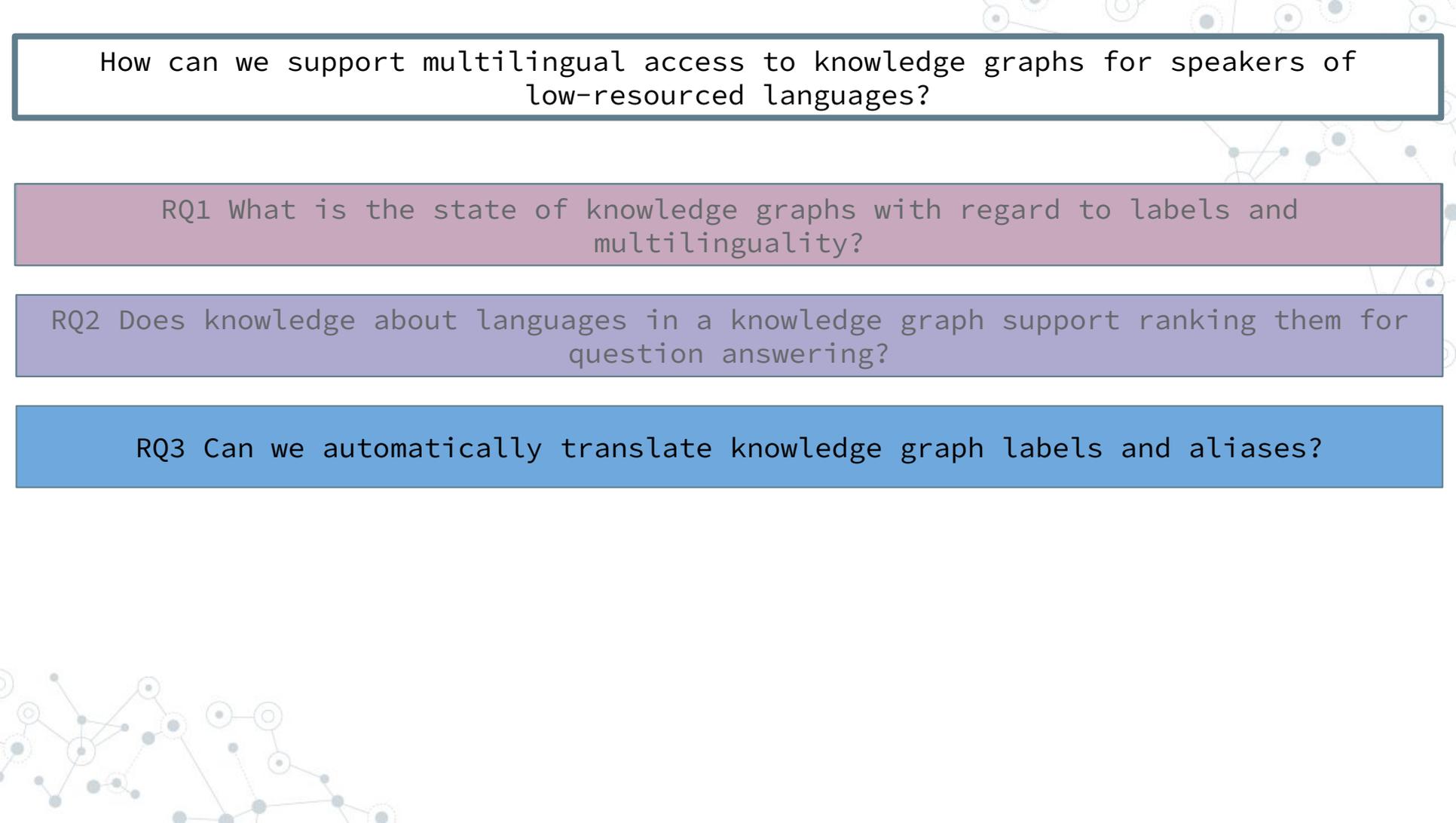


Capture knowledge about language and label coverage for each class in the knowledge graph

E.g. number of languages, label coverage

QALM dataset

- ◎ Based on QALD-9 (benchmark for multilingual QA over DBpedia, answers as entity URIs)
- ◎ Manual translation of SPARQL queries for five KGs
 - DBpedia, Wikidata, YAGO, MusicBrainz, LinkedMDB
- ◎ Answers in English, Spanish, Hindi
- ◎ Crowdsourced best answers
- ◎ Separated in domains, such as company, politics
- ◎ <https://github.com/luciekaffee/QALM>
(still has to be published somewhere properly)

A decorative background featuring a network graph with nodes and edges, primarily in shades of blue and grey, located in the top right and bottom left corners of the slide.

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Translation and transliteration of KG labels



- Entities in the *company* domain
- Can be translated or transliterated

Translation and transliteration of KG labels

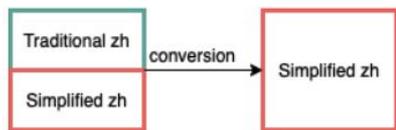


- Entities in the *company* domain
- Can be translated or transliterated

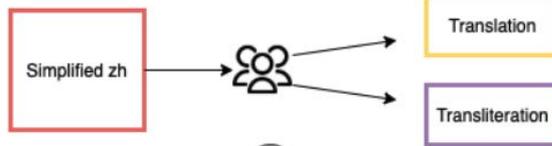
transfers the meaning of a word from one to another language

transfers a word from one script to another

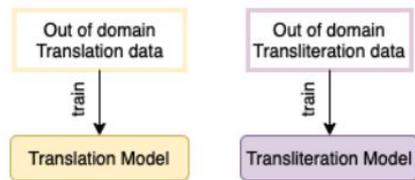
Translation and transliteration of KG labels



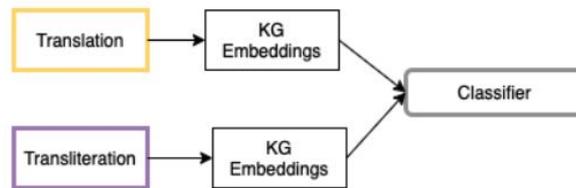
1



2

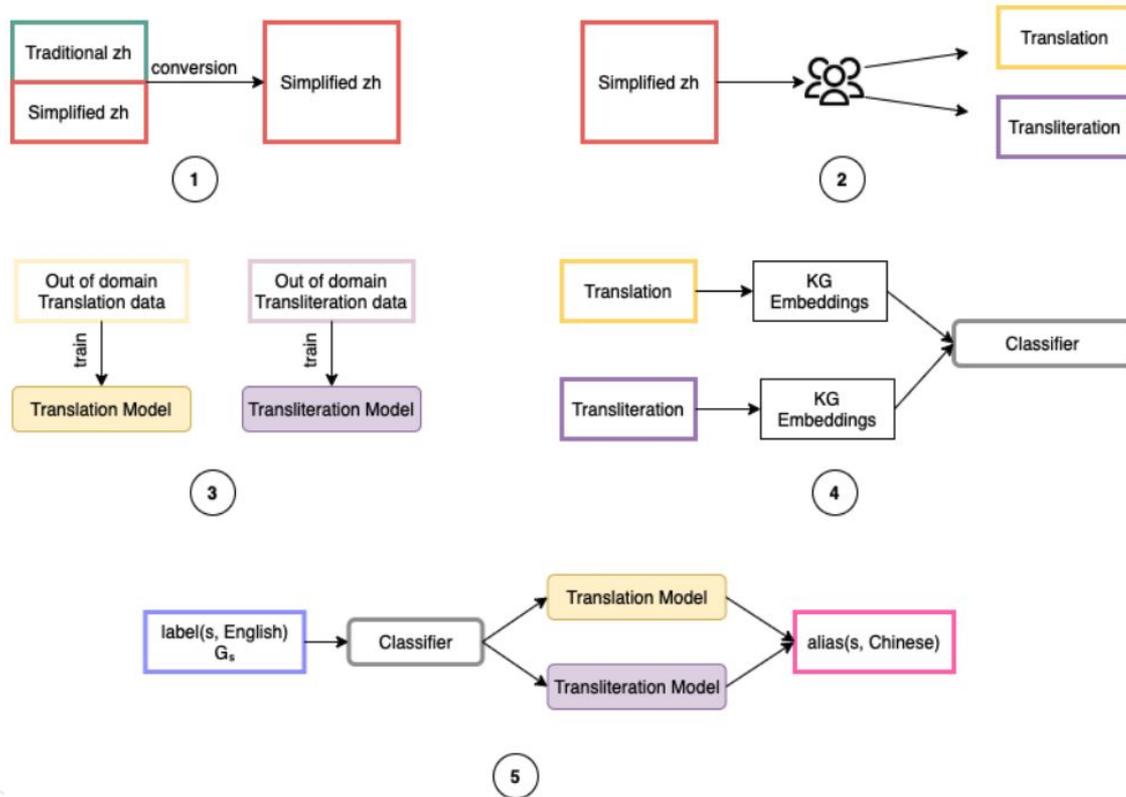


3



4

Translation and transliteration of KG labels



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Kaffee et al.: Mind the (Language) Gap: Generation of Multilingual Wikipedia Summaries from Wikidata for ArticlePlaceholders [ESWC 2018]; Kaffee et al.: Learning to Generate Wikipedia Summaries for Underserved Languages from Wikidata [NAACL 2018]; Kaffee et al.: Using Natural Language Generation to Bootstrap Missing Wikipedia Articles: A Human-centric Perspective [Semantic Web Journal 2021]

Article Placeholder on Wikipedia

مراكش



54

مُراكش هي مدينة مغربية تقع شمال البلاد .

حالة خاصة من

مدينة

معرفةات

معرف مكتبة البرلمان الوطني (NDL)

00629288

معرف فري بيس

m/054rw/

معرف جيونيمز

2542997

بداية (تدشين)

1062

التسمية المحلية

مراكش (العربية)

□□□□□□ (الآمازيغية وسط الأطلس)

Triples from Wikidata

مراكش



54

معرفة

معرفة مكتبة البرلمان الوطني (NDL)

00629288

معرفة فري بيس

m/054rw/

معرفة جيونيمز

2542997

مُراكش هي مدينة مغربية تقع شمال البلاد .

حالة خاصة من

مدينة

بداية (تدشين)

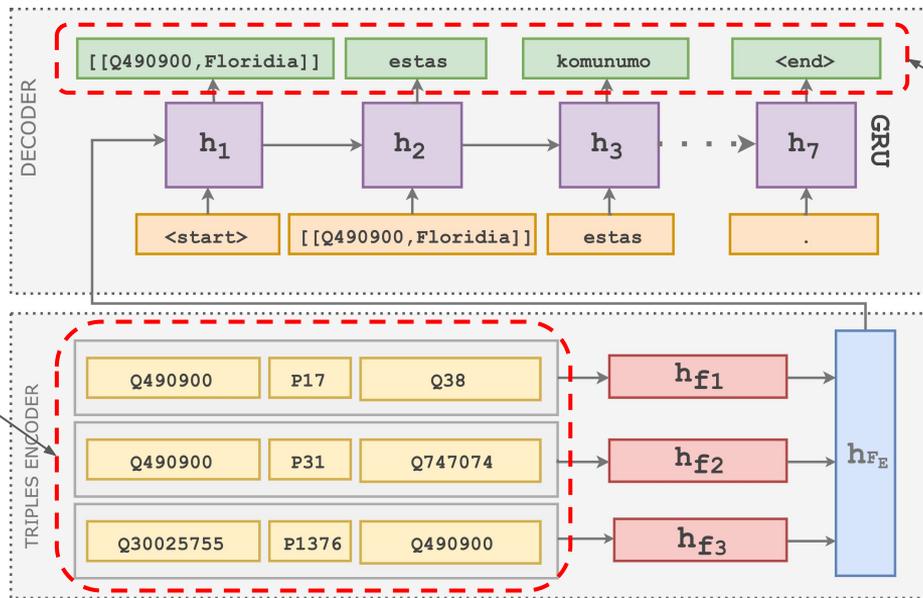
1062

التسمية المحلية

مراكش (العربية)

□□□□□□ (الآمازيغية وسط الأطلس)

Text generation from Wikidata for Wikipedia in low-resource languages



Encoded Wikidata Triples

Generation of 1-2 sentences descriptions of the input triples.

Generated description of the topic

مراكش



51

مُراكش هي مدينة مغربية تقع شمال البلاد .

حالة خاصة من

مدينة

معارف

معرف مكتبة البرلمان الوطني (NDL)

00629288

معرف فري بيس

m/054rw/

معرف جيونيمز

2542997

بداية (تدشين)

1062

التسمية المحلية

مراكش (العربية)

□□□□□□ (الآمازيغية وسط الأطلس)

- Tested with Wikipedia readers in Arabic and Esperanto
- Results of the reader study:
We generate sentences of comparable fluency, that “feel” like Wikipedia sentences

		Fluency	Appropriateness	
		Mean	SD	Part of Wikipedia
Arabic	Ours	4.7	1.2	77%
	Wikipedia	4.6	0.9	74%
	News	5.3	0.4	35%
Esper.	Ours	4.5	1.5	69%
	Wikipedia	4.9	1.2	84%
	News	4.2	1.2	52%

Study with Wikipedia editors: We generate sentences that are highly reused by editors

	Category	Examples	%
Arabic	WD	<p><u>خماسي كلوريد الزرنيخ مركب كيميائي له الصيغة (كلمة ناقصة) ، ويكون على شكل بلورات بيضاء.</u>^A</p> <p><u>خماسي كلوريد الزرنيخ هو مركب كيميائي له الصيغة (AtClu2085) ، ويكون على شكل بلورات بيضاء.</u>^B</p>	45.45%
	PD	<p><u>بيتش باتوم (بالإنجليزية (كلمة ناقصة) Ohio) هي منطقة سكنية تقع في الولايات المتحدة في (كلمة ناقصة).</u>^D</p> <p><u>بيتش باتوم (بالإنجليزية: Beach Batom) هي قرية تقع في الولايات المتحدة الامريكية في برووك كاونتي.</u>^C</p>	33.33%
	ND	<p><u>دير علا هي بلدة تقع في جنوب غرب إيران.</u>^F</p> <p><u>دير علا، أو بيثر ، هي قرية أردنية</u>^F</p>	21.21%
Esperanto	WD	<p><u>Zederik estas komunumo en la nederlanda provinco Zuid-Holland.</u>^G</p> <p><u>Zederik estas komunumo en la nederlanda provinco Zuid-Hooland</u>^G kaj estas ĉirkaŭata de la municipoj Lopik kaj Zederik.</p>	78.98%
	PD	<p><u>Nova Pádua estas municipo en la brazila subŝtato Suda Rio-Grando</u>^H kiu havis (manka nombro) loĝantojn en (jaro).</p> <p><u>Nova Pádua estas municipo en la brazila subŝtato Suda Rio-Grando.</u>^H</p>	15.79%
	ND	<p><u>Ibiúna estas municipo de la brazila subŝtato San-Paŭlo, kiu taksis (manka nombro) enloĝantojn en (jaro).</u>^I</p> <p><u>Ibiúna estas brazila [[municipo]] kiu troviĝas en la administra unuo [[San-Paŭlo]].</u>^J</p>	5.26%

- Interview with Wikipedia editors across 6 languages
- Mistakes by the network are ignored
- Can lead to too much trust (no provenance of the text)
- “magical threshold” for the length of a generated text
- Good for new editors (as a starting help)

Language	Sentence displayed to participants	# Participants
Arabic (ar)	مَرَاكُش (بالأمازيغية: <rare>) هي مدينة مغربية تقع شمال البلاد.	4
Swedish (sv)	Marrakech (arabiska <rare>, Berberspråk <rare>) är en stad i sydvästra Marocko, vid foten av <rare>.	2
Hebrew (he)	מרקש (בערבית: <rare>) היא עיר מדברית בדרום מערב מרוקו למרגלות הרי <rare>.	1
Persian (fa)	شهر مراکش (به بربری: <rare>) یکی از شهرهای کشور مراکش و مرکز استان مراکش <rare> است.	1
Indonesian (id)	Marrakesh (Arab: <rare>) ialah kota di barat daya Maroko di kaki <rare>.	1
Ukrainian (uk)	Марракеш (араб. <rare>) — важливе імперське місто в Марокко, розташованого біля підніжжя гір <rare>.	1



A decorative network diagram in the top-left corner, consisting of interconnected nodes and lines, rendered in a light gray color. The nodes are represented by small circles, some of which are larger and have a double-circle outline, suggesting a hierarchy or different types of nodes. The lines are thin and connect the nodes in a complex, web-like structure.

Outlook on recent work

A decorative network diagram in the bottom-right corner, similar to the one in the top-left, consisting of interconnected nodes and lines in a light gray color. The nodes are small circles, some larger with double outlines, connected by thin lines in a complex web structure.

Entity linking over varying KBs with time

- Time-stratified English Wikipedia snapshots from 2013 to 2022
- Entities that change over time and newly introduced entities for each year
- Decrease of existing entity linking approaches by 3.1% for existing, changing entities
- For new entities this accuracy drop is up to 17.9%

Probing PTLMs for cross-cultural differences in values

- LMs embed knowledge about cultures and values
- Probing how those values align with previous social-science studies of cross-cultural values
- PTLMs capture differences across cultures, i.e., there are differences in the values across different language PTLMs
- Those do not align with previous studies of cross-cultural differences in values

Papers

- Zaporojets et al.: TempEL: Linking Dynamically Evolving and Newly Emerging Entities [Neurips 2022]
- Arora et al.: Probing Pre-Trained Language Models for Cross-Cultural Differences in Values
- Kaffee et al.: Using Natural Language Generation to Bootstrap Missing Wikipedia Articles: A Human-centric Perspective [Semantic Web Journal 2022]
- Amaral et al.: Assessing the Quality of Sources in Wikidata Across Languages: A Hybrid Approach [Semantic Web Journal 2021]
- Kaffee et al.: Ranking Knowledge Graphs By Capturing Knowledge about Languages and Labels [KCAP 2019]
- Kaffee et al.: When Humans and Machines Collaborate: Cross-lingual Label Editing in Wikidata [OpenSym 2019]
- Kaffee and Simperl: The Human Face of the Web of Data: A Cross-sectional Study of Labels [SEMANTiCS 2018]
- Kaffee et al.: Mind the (Language) Gap: Generation of Multilingual Wikipedia Summaries from Wikidata for ArticlePlaceholders [ESWC 2018]
- Kaffee et al.: Learning to Generate Wikipedia Summaries for Underserved Languages from Wikidata [NAACL 2018]
- Kaffee and Simperl: Analysis of Editors' Languages in Wikidata [OpenSym 2018]
- Pellissier Tanon and Kaffee: Property Label Stability in Wikidata: Evolution and Convergence of Schemas in Collaborative Knowledge Bases [WikiWorkshop @ WWW 2018]
- Vougiouklis et al.: Neural Wikipedia: Generating Textual Summaries from Knowledge Base Triples [Journal of Web Semantics 2018]
- Kaffee et al.: A glimpse into Babel: an analysis of multilinguality in Wikidata [OpenSym 2017]
- Piscopo et al.: Provenance Information in a Collaborative Knowledge Graph: an Evaluation of Wikidata External References [ISWC 2017]
- Piscopo et al.: What do Wikidata and Wikipedia Have in Common? An Analysis of their Use of External References [OpenSym 2017]

Grants & Awards

- 2022: SWSA Distinguished Dissertation Award
- 2020: Scribe's reference API, *WikiCred Project Grant*
- 2019: Scribe: Supporting Under-resourced Wikipedia Editors in Creating New Articles, *Wikimedia Project Grant*
- 2016: Marie Skłodowska-Curie ITN PhD Fellowship