

## Lecture 6 - Advanced Knowledge Graph Applications

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## Autumn 2020





# Knowledge Graphs

## Lecture 6: Advanced Knowledge Graph Applications

6.1 The Graph in Knowledge Graphs

6.2 Knowledge Graph Embeddings

**6.3 Knowledge Graph Completion**

6.4 Knowledge Graph Mappings and Alignment

6.5 Semantic Search

6.6 Exploratory Search and Recommender Systems

# How complete are Knowledge Graphs?

- Check whether all **Climatologists** in **DBpedia** are labelled as such also in **wikidata**



```
PREFIX dct: <http://purl.org/dc/terms/>
PREFIX dbc: <http://dbpedia.org/resource/Category:>

SELECT DISTINCT ?wditem ?wditemLabel WHERE {
  SERVICE <http://dbpedia.org/sparql> {
    ?item dct:subject dbc:Climatologists ;
    owl:sameAs ?wditem FILTER regex (?wditem, "wikidata.org") .
  }
  SERVICE <https://query.wikidata.org/sparql> {
    ?wditem wdt:P106 ?occupation FILTER NOT EXISTS {?wditem wdt:P106 wd:Q1113838 }.
    ?wditem rdfs:label ?wditemLabel FILTER (LANG(?wditemLabel)="en") .
  }
}
```



# How complete are Knowledge Graphs?

- Check whether all Climatologists in DBpedia are labelled as such also in wikidata

[SPARQL query](#)



```

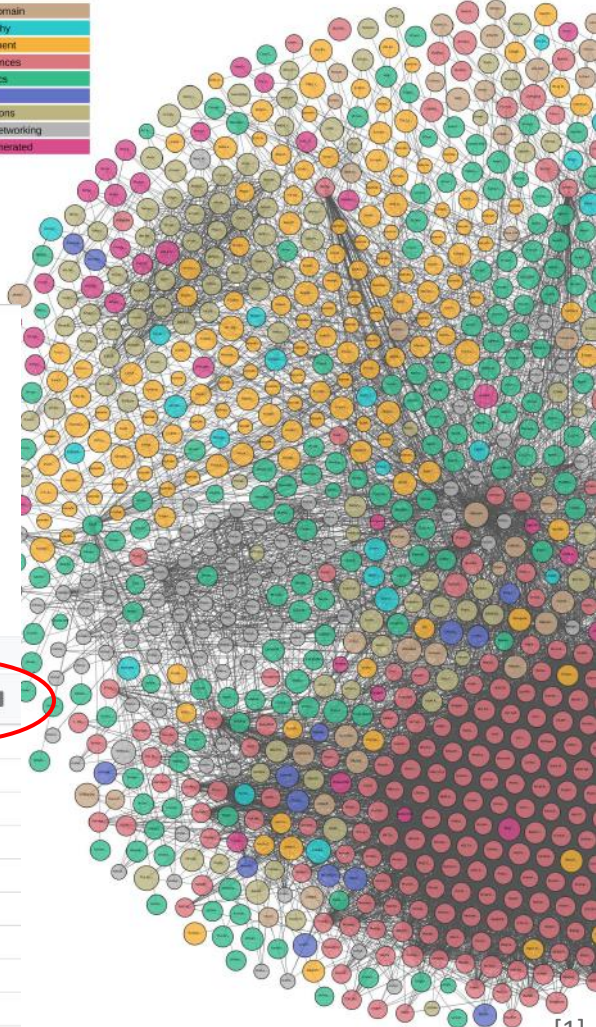
1 PREFIX dct: <http://purl.org/dc/terms/>
2 PREFIX dbc: <http://dbpedia.org/resource/Category:>
3
4 SELECT DISTINCT ?wditem ?wditemLabel WHERE {
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8   }
9   SERVICE <https://query.wikidata.org/sparql> {
10    ?wditem wdt:P106 ?occupation FILTER NOT EXISTS {?wditem wdt:P106 wd:Q1113838 }.
11    ?wditem rdfs:label ?wditemLabel FILTER (LANG(?wditemLabel)="en") .
12  }
13 }

```

15 Climatologists are missing

15 results in 515 ms

wditem	wditemLabel
Q670496	Veerabhadran Ramanathan
Q6610163	list of climate scientists
Q1348480	Henrik Svensmark
Q6396209	Kevin E. Trenberth
Q4714955	Aleksander Kosiba
Q462297	Atsumu Ohmura
Q16256092	T. N. Krishnamurti
Q112648	Rudolf Ferdinand Spitaler
Q7282186	Rafael L. Bras



# Knowledge Graph Refinement

- As a model of the real world or a part of it, **knowledge graphs cannot reasonably reach full coverage**, i.e., contain information about each and every entity in the universe.
- **It is unlikely**, in particular if heuristic methods are applied for knowledge graph construction, **that the knowledge graph is fully correct**.
- To address those shortcomings, various methods for **Knowledge Graph Refinement** have been proposed, as e.g.
  - Deduplicating entity nodes (entity resolution)
  - Collective reasoning (probabilistic soft logic)
  - **Link prediction** or **Knowledge Graph Completion**
  - Dealing with missing values
  - Anything that improves an existing knowledge graph

# Completion vs. Error Detection

- **Knowledge Graph Completion:**

Adding missing knowledge to the Knowledge Graph

E.g. adding a triple:

*<JosephFourier, occupation, Physicist>*

- **Error Detection:**

Identifying wrong information in the Knowledge Graph

E.g. finding inconsistencies:

*<JosephFourier, isA, Human>*

*<JosephFourier, isA, FictionalCharacter>*

# Knowledge Graph Completion

- A promising approach for **Knowledge Graph Completion** is
  - to embed Knowledge Graphs into latent spaces (via Knowledge Graph Embeddings) and
  - make inferences by learning and operating on latent representations.
- Such embedding models, however, **do not make use of any rules** during inference and hence have limited accuracy.
- E.g. predict that in wikidata the following fact may be complemented:

*(AtsumoOmuhura occupation Climatologist)*

wd:Q462297 wdt:P106 **wd:Q1113838** .

Tail Prediction

# Link Prediction

	Task	Example	Result
Link Prediction	Triple Classification	(JosephFourier, occupation, physicist)?	(yes, 95%)
	Tail Prediction	(JosephFourier, occupation, ?)	(1, physicist, 0.95), (2, chemist, 0.93) ...
	Head Prediction	(?, occupation, physicist)	(1, AlbertEinstein, 0.91) (2, StephenHawking, 0.90)
	Relation Prediction	(JosephFourier, ?, physicist)	(1, occupation, 0.95)
	Entity Classification (Type Prediction)	(JosephFourier, isA, ?)	(1, Person, 0.99) (2, Human, 0.99),...



# Type Prediction

- **Predicting a type or class** for an entity given some characteristics of the entity is a very common problem in machine learning, known as **classification**.

<JosephFourier, isA, ?>

- **Supervised Learning Approach:**
  - Type Prediction can be addressed via a **classification model** based on **labeled training data**,
  - typically the set of entities in a Knowledge Graph which have types attached.

# Type Prediction

- **Multi-Class Prediction:**

- In Knowledge Graphs usually there are more than two types/classes of entities to distinguish

E.g. Classes Physicists, Chemists, Climatologists, etc.

- **Single-Label Classification:**

- Only one type/class can be assigned per entity

E.g.: <JosephFourier, isA, Person>

- **Multi-Label Classification:**

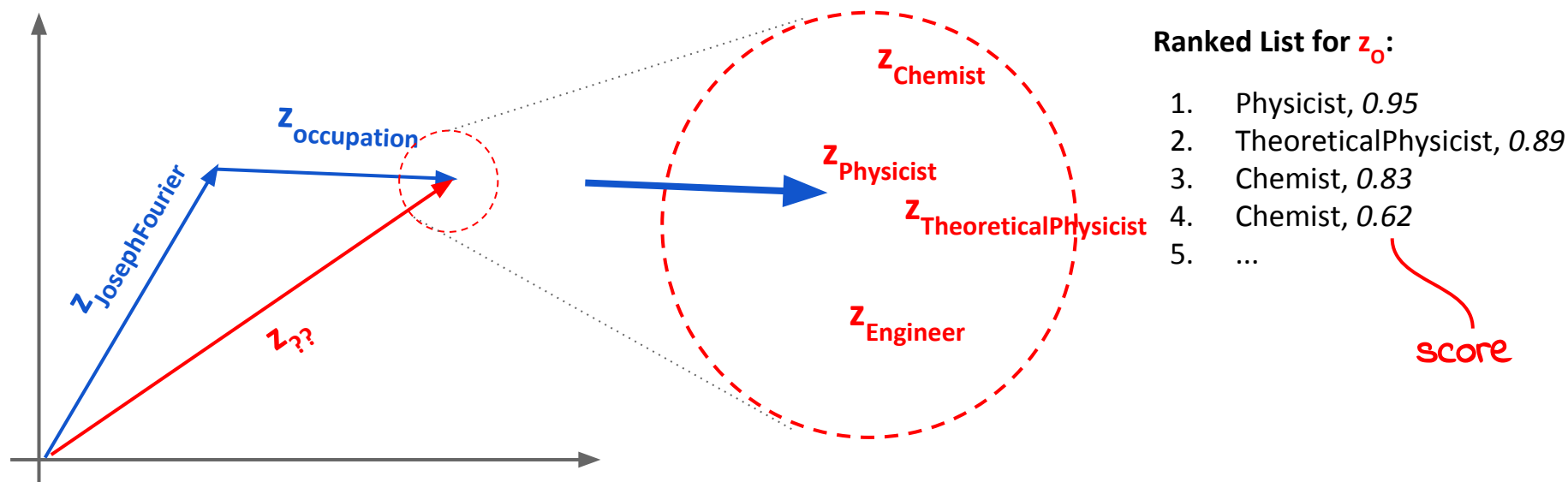
- In Knowledge Graphs some entities might allow for the assignment of more than one type

E.g.: <electron, isA, Particle> and  
<electron, isA, Wave>

# Methods for Knowledge Graph Link Prediction

## ● Use Translational Embeddings

- **Unsupervised** methods, e.g. TransE, use  $\mathbf{z}_s + \mathbf{z}_p$  to predict  $\mathbf{z}_o$
- **Supervised** Methods for prediction based on embedding vectors





Tabula terræ Nouæ Zemblæ,  
in qua fretum sinusq; WAIGATS,  
item ora littoralis TARTARIÆ atq;  
RUSSIÆ, ad urbem usq; KILDEINAM,  
præscriptum adhuc cursus quem inde  
naues in reditu tenent scilicet septentrionalis  
littus et TRAIECTUS  
prope fretum WAIGATS ad Rusiæ  
oram et ad promontorium CANDENOS  
atq; fauces usq; MARIS ALBI.  
AUTHORE GERHARDO DE VEER.

# Knowledge Graph Mappings and Alignment



### Picture References:

- [1] John P. McCrae, The Linked Open Data Cloud, [CC-BY-4.0]  
<https://lod-cloud.net/>
- [2] Tabula terrae Nouae Zemblae in qua fretum sinusq Waigats item ord littoralis Tartariae atq Russiae, ad urgem usq Kildeinam, Authore Gerhardo De Veer. 1601,  
[https://commons.wikimedia.org/wiki/File:1601\\_De\\_Bry\\_and\\_de\\_Veer\\_Map\\_of\\_Nova\\_Zembla\\_and\\_the\\_Northeast\\_Passage\\_-\\_Geographicus\\_-\\_NovaZembla-debry-1601.jpg](https://commons.wikimedia.org/wiki/File:1601_De_Bry_and_de_Veer_Map_of_Nova_Zembla_and_the_Northeast_Passage_-_Geographicus_-_NovaZembla-debry-1601.jpg)