Word2Vec and Metadata Records

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April 2019

Overview

- Motivation
- Aspects of word2vec
- Processing of metadata records: input and pre-preprocessing
- Metadata records and word2vec: example output & optimization
- Application: recommendation based on metadata semantic similarity
- Next steps

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Motivation – from the perspective of applications in digital libraries

- Libraries usually provide metadata records e.g. to facility keyword based search
- Similarity of metadata records is hard to compute on a semantic level
    - “Germany” is closely related to “Europe”
    - This relation is not explicit in metadata records

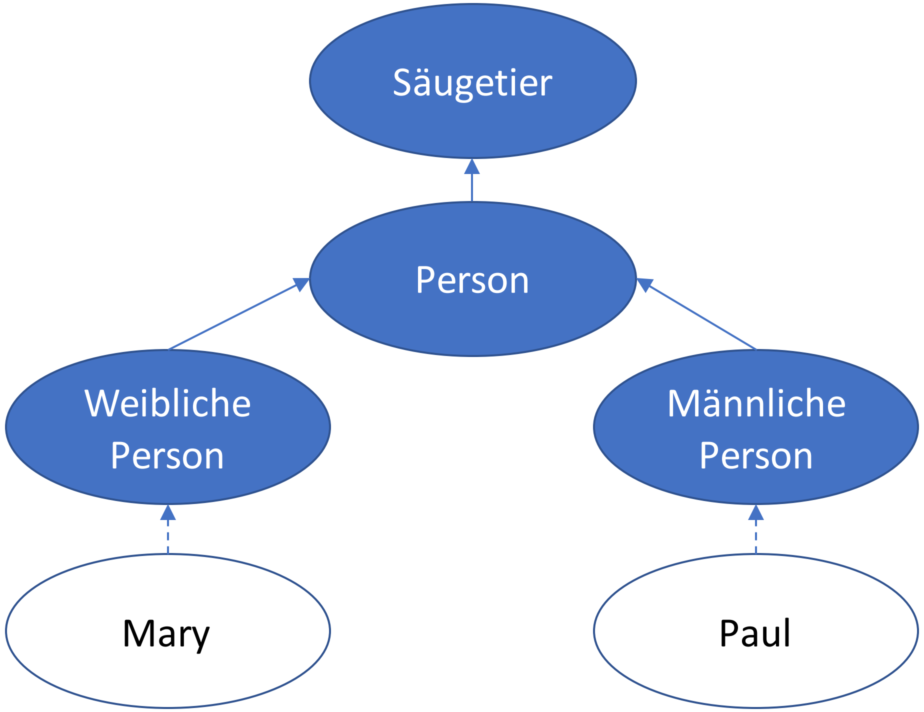
Motivation – from the perspective of applications in digital libraries

- word2vec is an unsupervised learning approach that calculates semantic similarity
- Goals
  - Apply word2vec to metadata records
  - Evaluate outcome using various word2vec settings
  - Show example application: word2vec based recommender system

Motivation – from the perspective of applied computational linguistics research

- Symbolic AI

  Knowledge crafted by humans



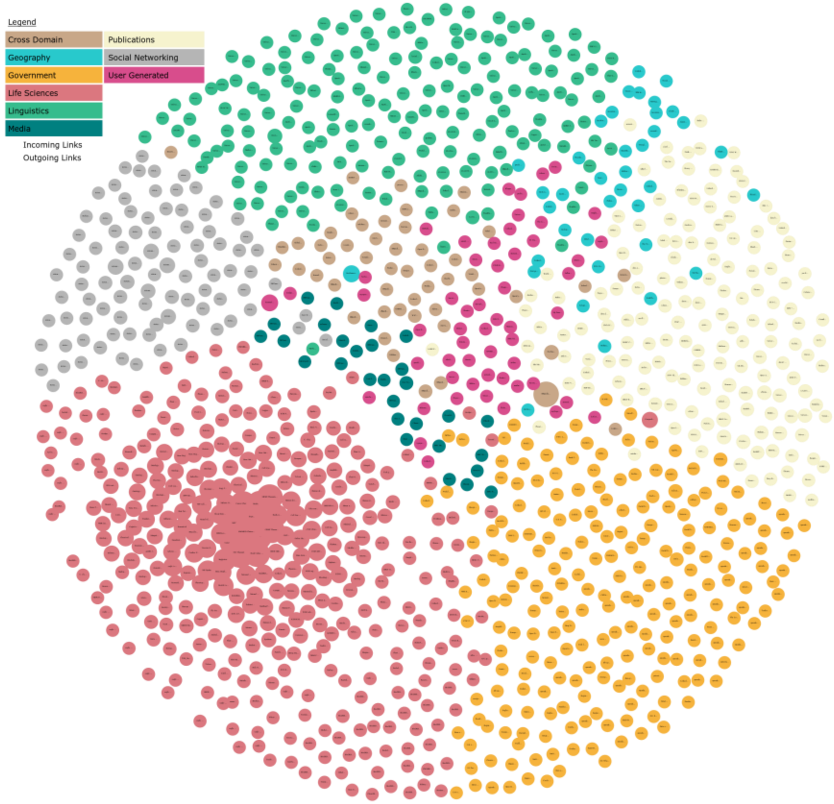
- **Machine Learning**

  Example: computer learns „what is a cat“?

Source: https://arxiv.org/pdf/1112.6209v3.pdf

Motivation – from the perspective of applied computational linguistics research

Linked (open) data sources



Input to machine learning

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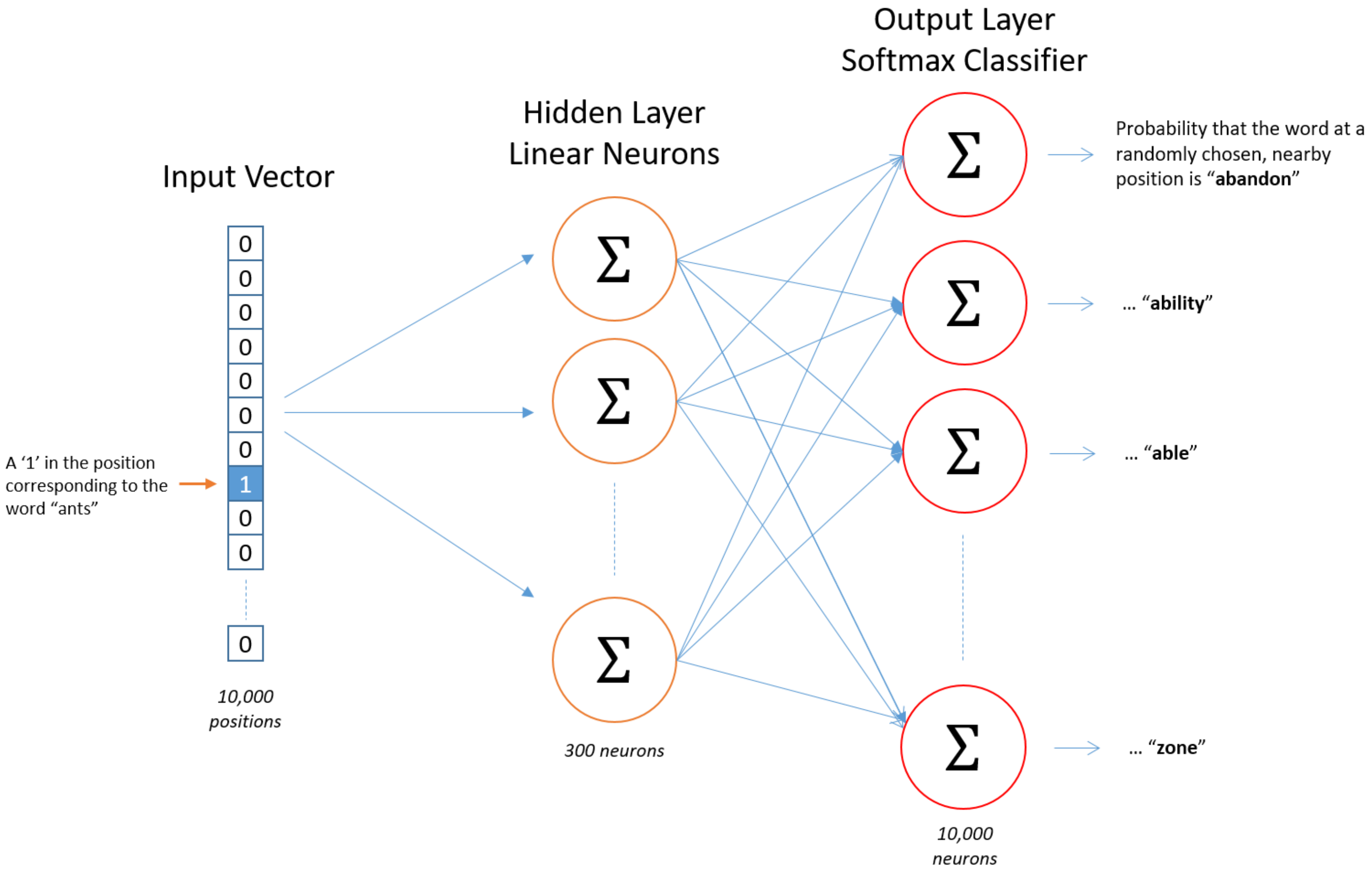
word2vec

- Unsupervised machine learning approach
- Used to calculate word embeddings
  - Representation of a vocabulary of words as numeric vectors
- Pivotal paper: Mikolov et al. (2013)
  - “Efficient Estimation of Word Representations in Vector Space”. In: proceedings of International Conference on Learning Representations 2013
- Basis: neural network – but not learning of weights for creating output
  - Learning of weights as the means to represent words
  - Using a single hidden layer
  - Similar to autoencoder approach

word2vec task

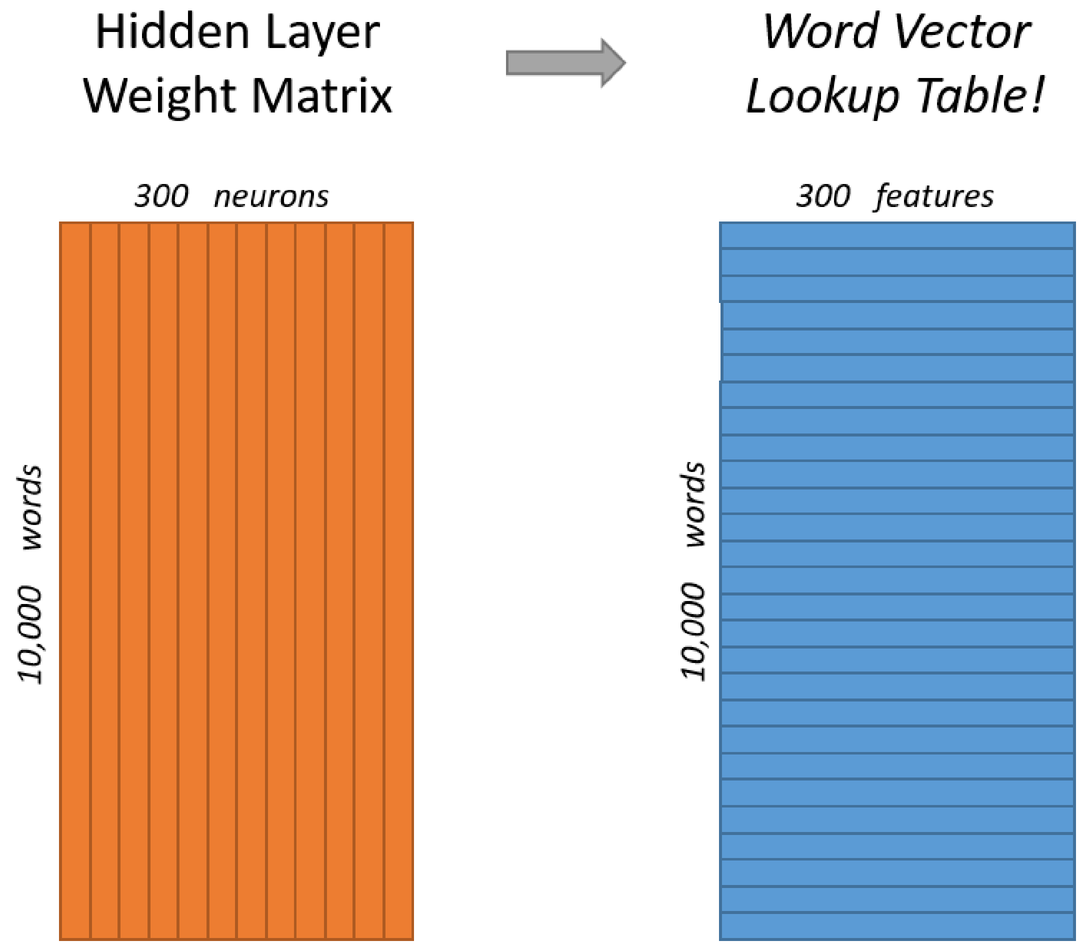
- Input: set of sentences
- Each word in sentence is processed with regards to neighbouring words – the window size
- Example sentence with window size 2
  - “The <u>cat</u> sat on the mat.”
    - the: the, cat; the, sat
    - cat: the, cat; cat, sat; cat, on
    - sat: the, sat; cat, sat; sat, on; sat, the
    - …
- Similarity = higher for words with the same context
  - “The <u>dog</u> sat on the mat.”

word2vec architecture



Source http://mccormickml.com/2016/04/19/word2vec-tutorial-the-skip-gram-model/

Learning in word2vec: using hidden layer as lookup table



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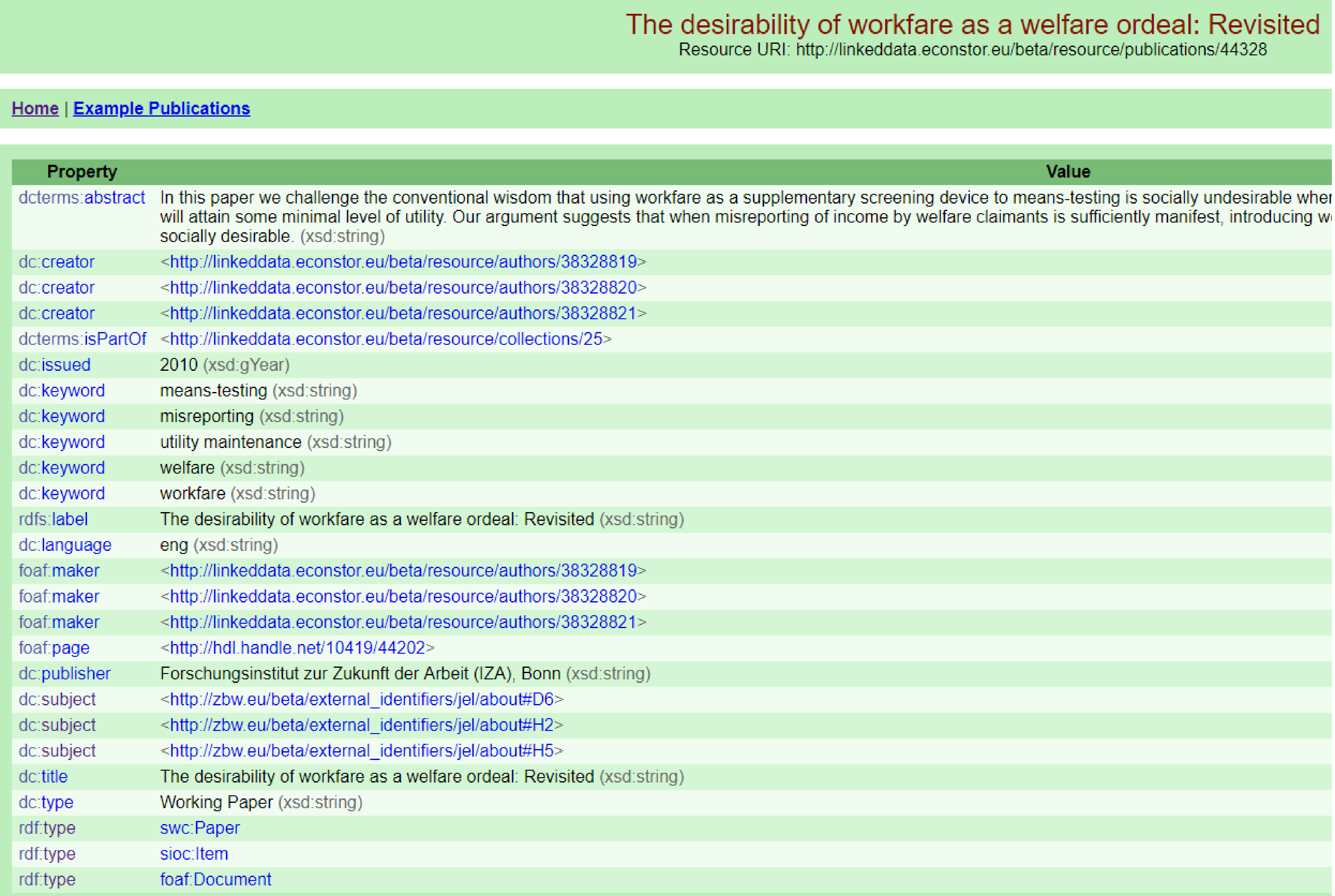
Processing of metadata records: input

- Using metadata available as linked data via EconStor LOD http://zbw.eu/labs/en/project/econstor-lod
    - Basis: Data from Leibniz Information Centre for Economics (ZBW)
    - Available as linked data
    - Keywords in German and English
    - Example record, see next slide
- Processing of keywords, not textual description
- Approach: keywords in similar context have related meanings



The desirability of workfare as a welfare ordeal: Revisited

Resource URI: http://linkeddata.econstor.eu/beta/resource/publications/44328

Home | Example Publications

Property	Value
dcterms:abstract	In this paper we challenge the conventional wisdom that using workfare as a supplementary screening device to means-testing is socially undesirable whe will attain some minimal level of utility. Our argument suggests that when misreporting of income by welfare claimants is sufficiently manifest, introducing w socially desirable. (xsd:string)
dc:creator	<http://linkeddata.econstor.eu/beta/resource/authors/38328819>
dc:creator	<http://linkeddata.econstor.eu/beta/resource/authors/38328820>
dc:creator	<http://linkeddata.econstor.eu/beta/resource/authors/38328821>
dcterms:isPartOf	<http://linkeddata.econstor.eu/beta/resource/collections/25>
dc:issued	2010 (xsd:gYear)
dc:keyword	means-testing (xsd:string)
dc:keyword	misreporting (xsd:string)
dc:keyword	utility maintenance (xsd:string)
dc:keyword	welfare (xsd:string)
dc:keyword	workfare (xsd:string)
rdfs:label	The desirability of workfare as a welfare ordeal: Revisited (xsd:string)
dc:language	eng (xsd:string)
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foaf:page	<http://hdl.handle.net/10419/44202>
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dc:subject	<http://zbw.eu/beta/external_identifiers/jel/about#H2>
dc:subject	<http://zbw.eu/beta/external_identifiers/jel/about#H5>
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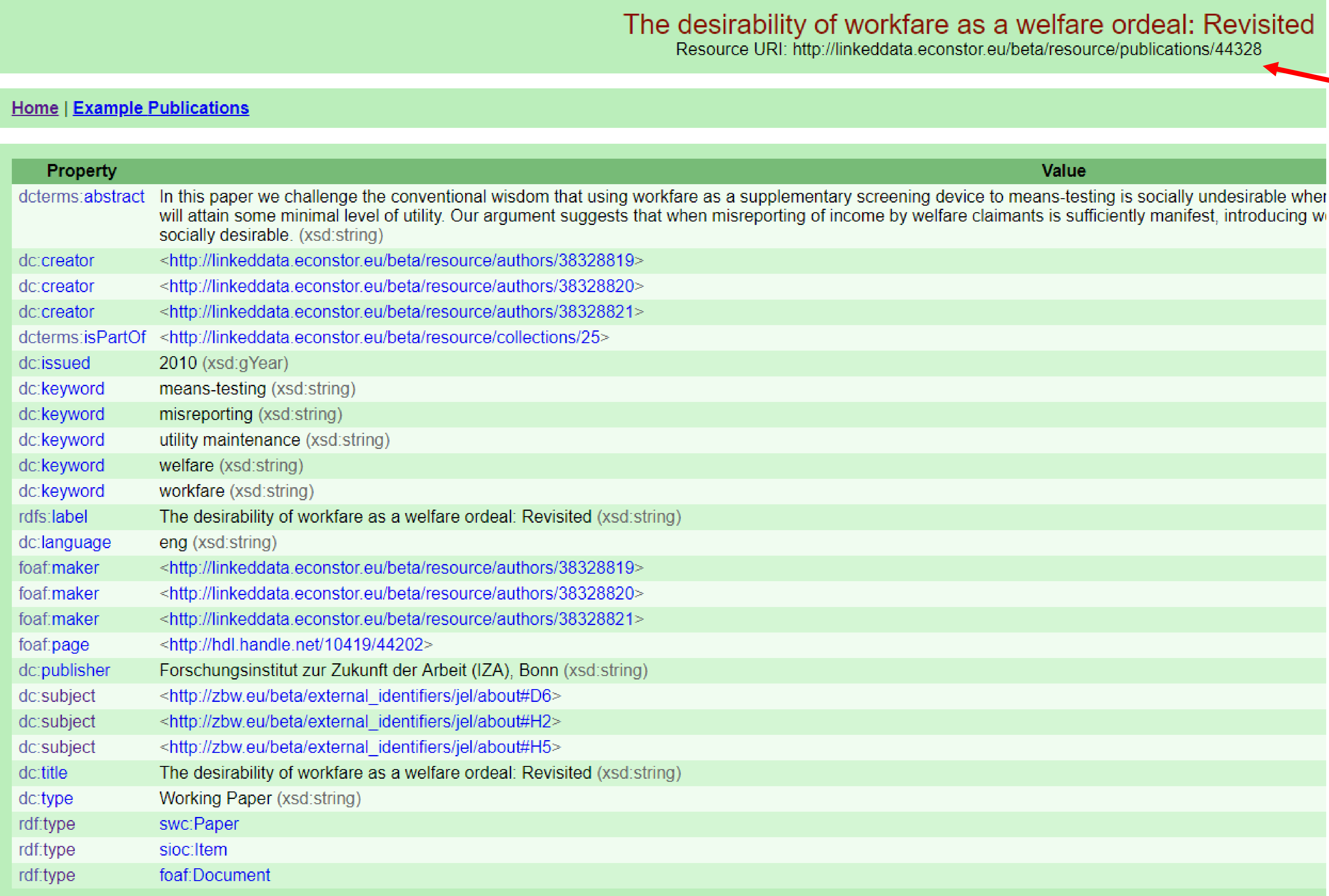
dc:type	Working Paper (xsd:string)
rdf:type	swc:Paper
rdf:type	sioc:Item
rdf:type	foaf:Document



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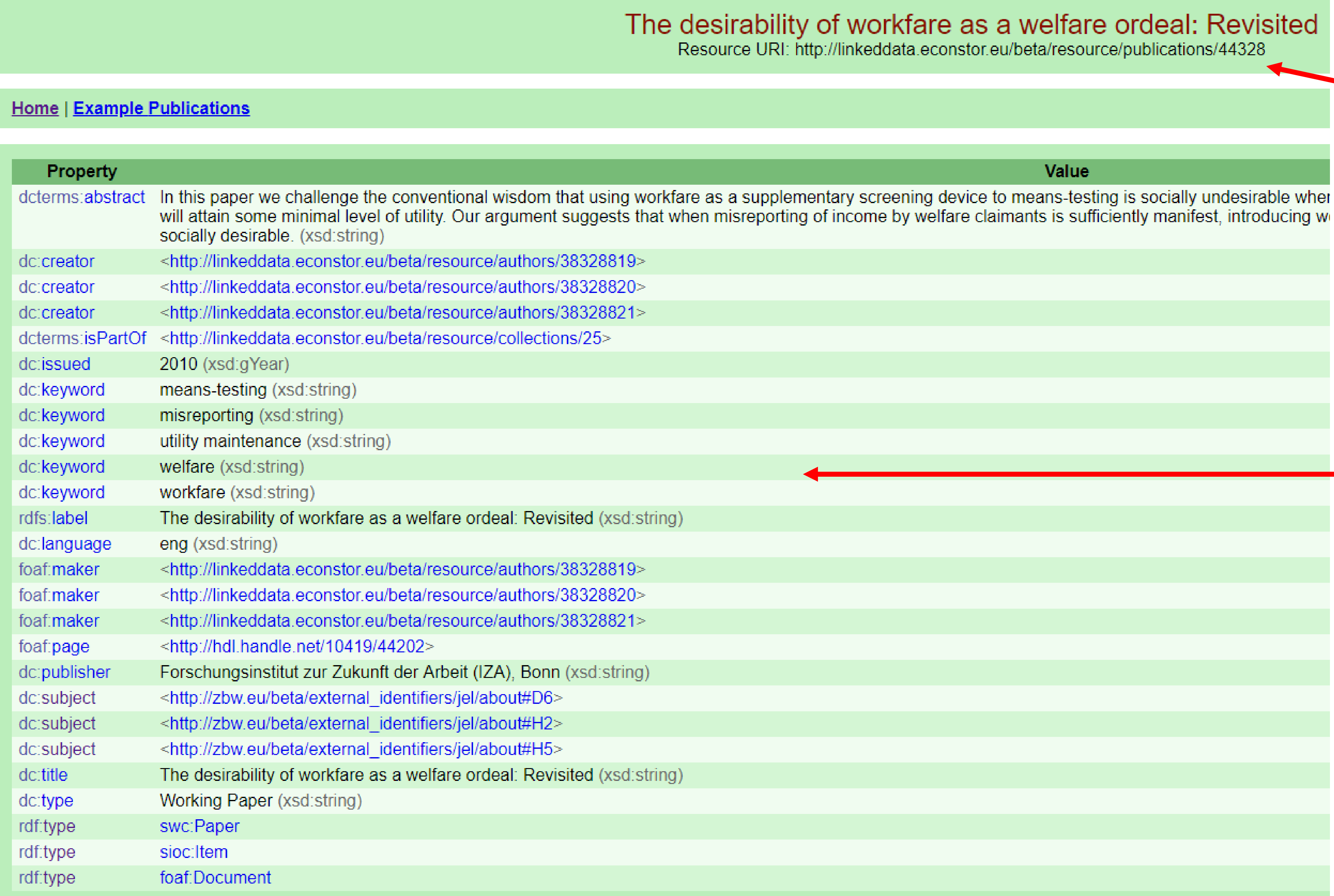
Canonical URI



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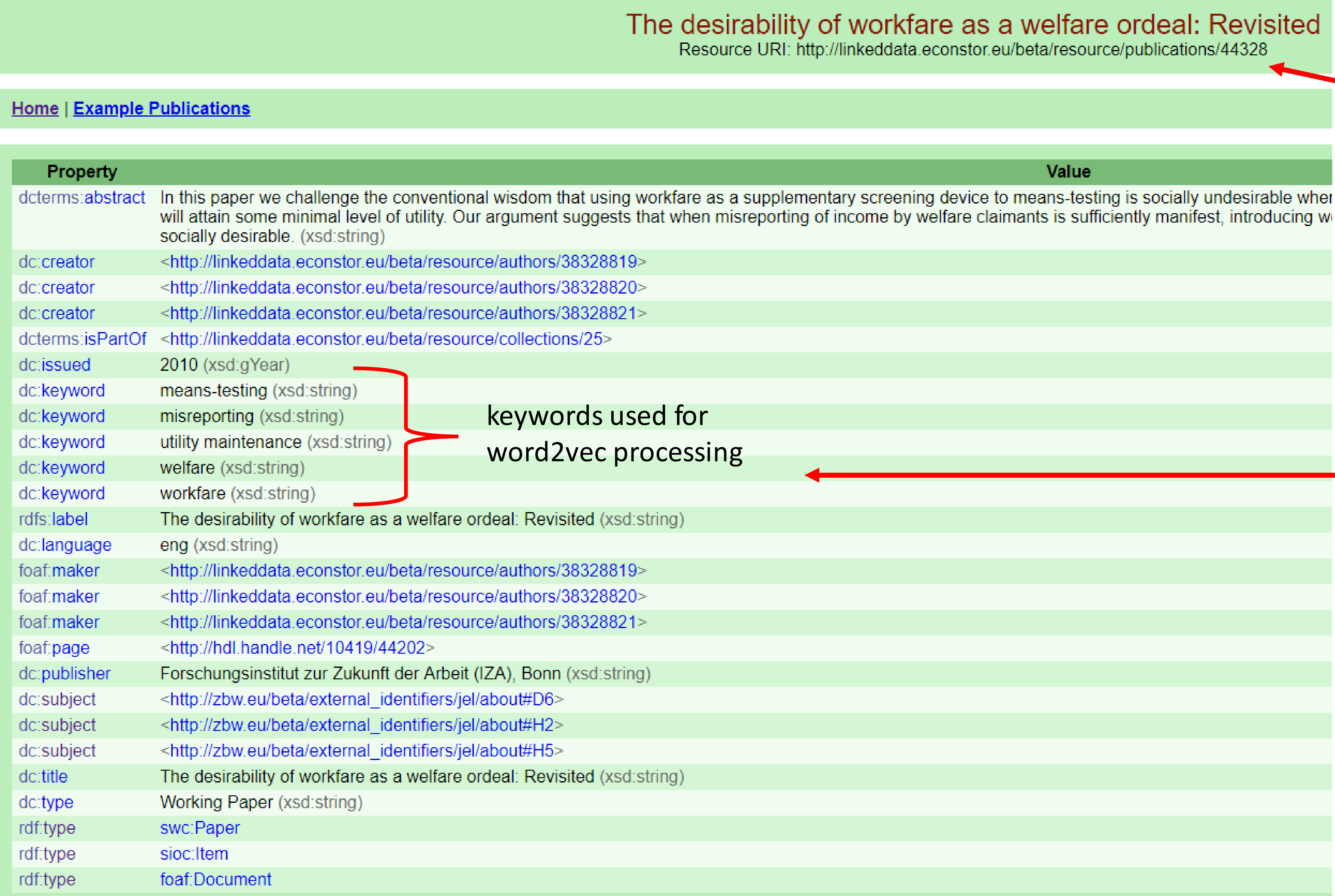
Canonical URI of publication

statements about publication



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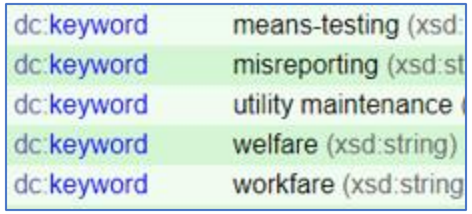
keywords used for word2vec processing

Canonical URI

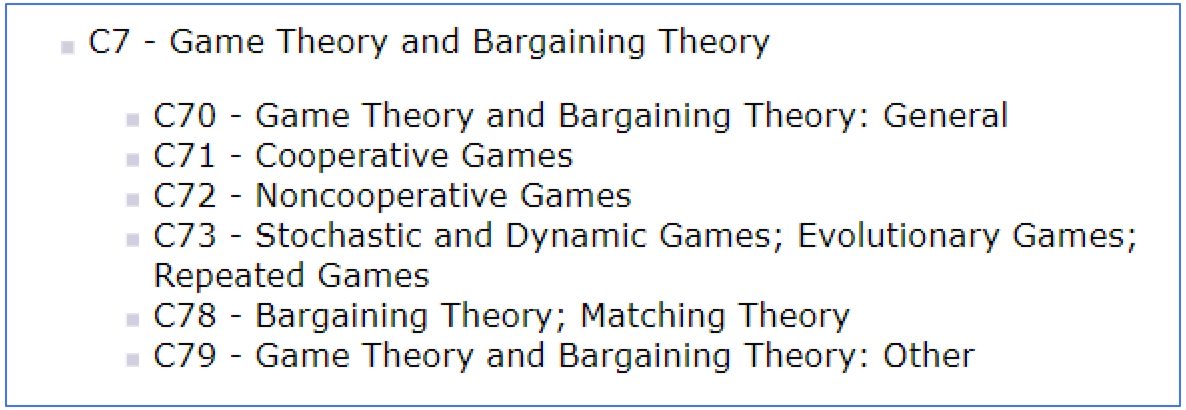
statements about publication

Why keywords?



dc:keyword	means-testing (xsd:
dc:keyword	misreporting (xsd:st
dc:keyword	utility maintenance (
dc:keyword	welfare (xsd:string)
dc:keyword	workfare (xsd:string

- word2vec processes tokens
- sets of keywords can be considered as sets of tokens, to be processed by word2vec
- Classification (part of EconStor) not used for word2vec: missing means to derive set of tokens from classification

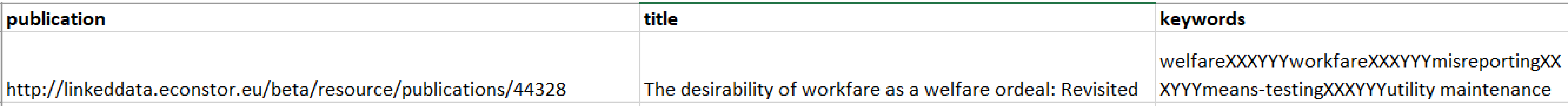


- C7 - Game Theory and Bargaining Theory
  - C70 - Game Theory and Bargaining Theory: General
  - C71 - Cooperative Games
  - C72 - Noncooperative Games
  - C73 - Stochastic and Dynamic Games; Evolutionary Games; Repeated Games
  - C78 - Bargaining Theory; Matching Theory
  - C79 - Game Theory and Bargaining Theory: Other

Pre-processing of data

- SPARQL Query to linked data endpoint at http://linkeddata.econstor.eu/beta/sparql
- Result: list of publications – for each publication
  - title
  - URI
  - keywords
- Sample output next slide

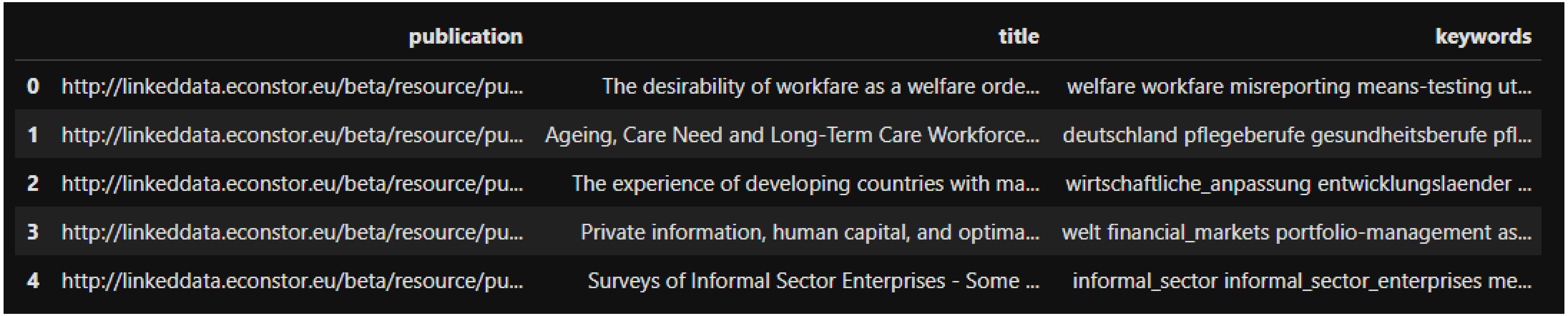
Sample output of pre-processing



publication	title	keywords
http://linkeddata.econstor.eu/beta/resource/publications/44328	The desirability of workfare as a welfare ordeal: Revisited	welfareXXXYYYworkfareXXXYYYmisreportingXXXYYYmeans-testingXXXYYYutility maintenance

- Keywords are temporarily separated via delimiter
- Before processing with word2vec, multi-token keywords are merged
  - Before: “wirtschaftliche anpassung”
  - After: “wirtschaftliche_anpassung”
- In that way, word2vec can calculate similarly per keyword, independent of the keyword internal segmentation
  - No need to remove stopwords, since we assume no internal structure for a keyword
- Input to word2vec (next slide)

Input to word2vec



	publication	title	keywords
0	http://linkeddata.econstor.eu/beta/resource/pu...	The desirability of workfare as a welfare orde...	welfare workfare misreporting means-testing ut...
1	http://linkeddata.econstor.eu/beta/resource/pu...	Ageing, Care Need and Long-Term Care Workforce...	deutschland pflegeberufe gesundheitsberufe pfl...
2	http://linkeddata.econstor.eu/beta/resource/pu...	The experience of developing countries with ma...	wirtschaftliche_anpassung entwicklungslaender ...
3	http://linkeddata.econstor.eu/beta/resource/pu...	Private information, human capital, and optima...	welt financial_markets portfolio-management as...
4	http://linkeddata.econstor.eu/beta/resource/pu...	Surveys of Informal Sector Enterprises - Some ...	informal_sector informal_sector_enterprises me...

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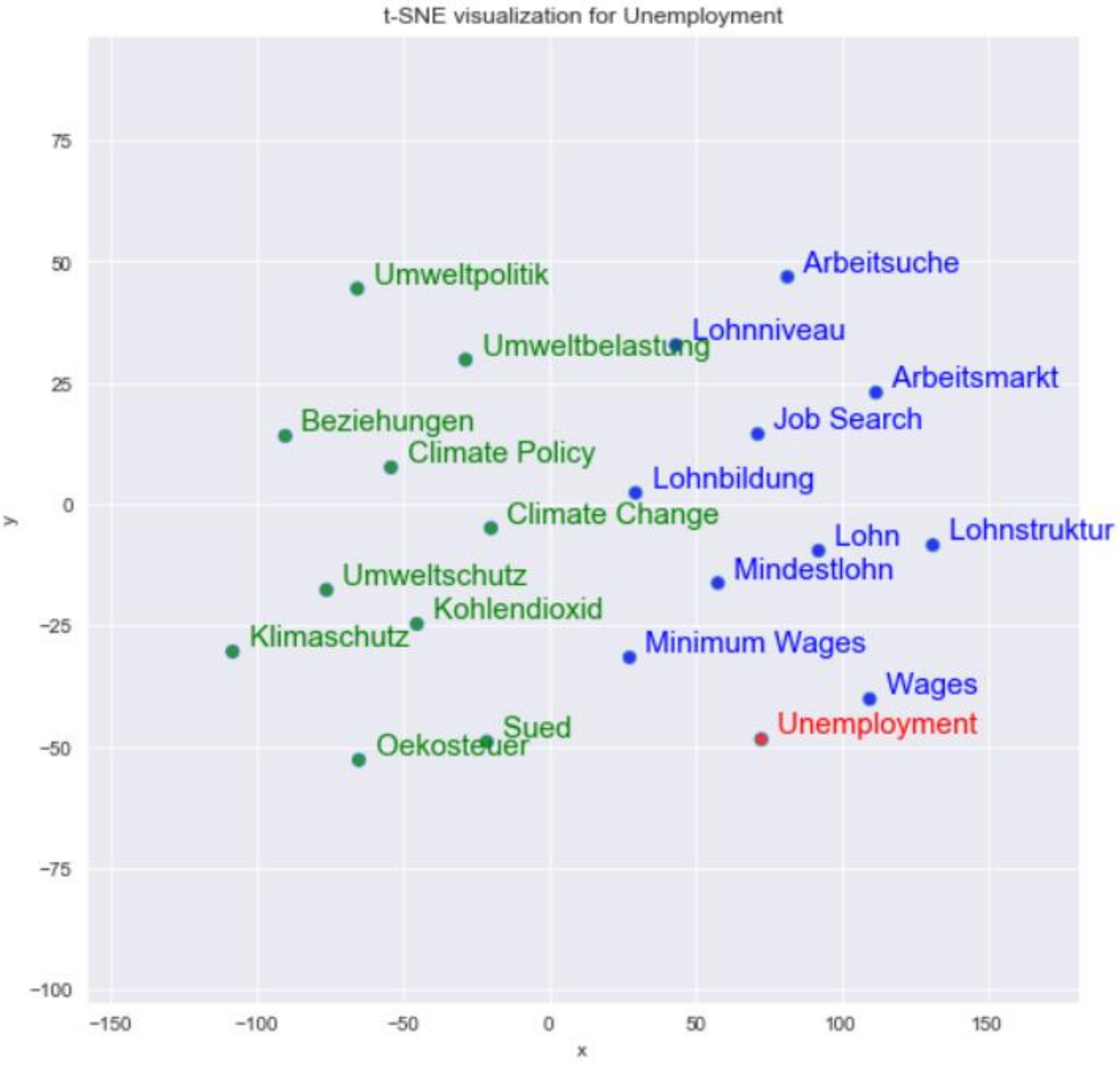
Library: gensim

- Widely used word2vec library
- See https://radimrehurek.com/gensim/index.html

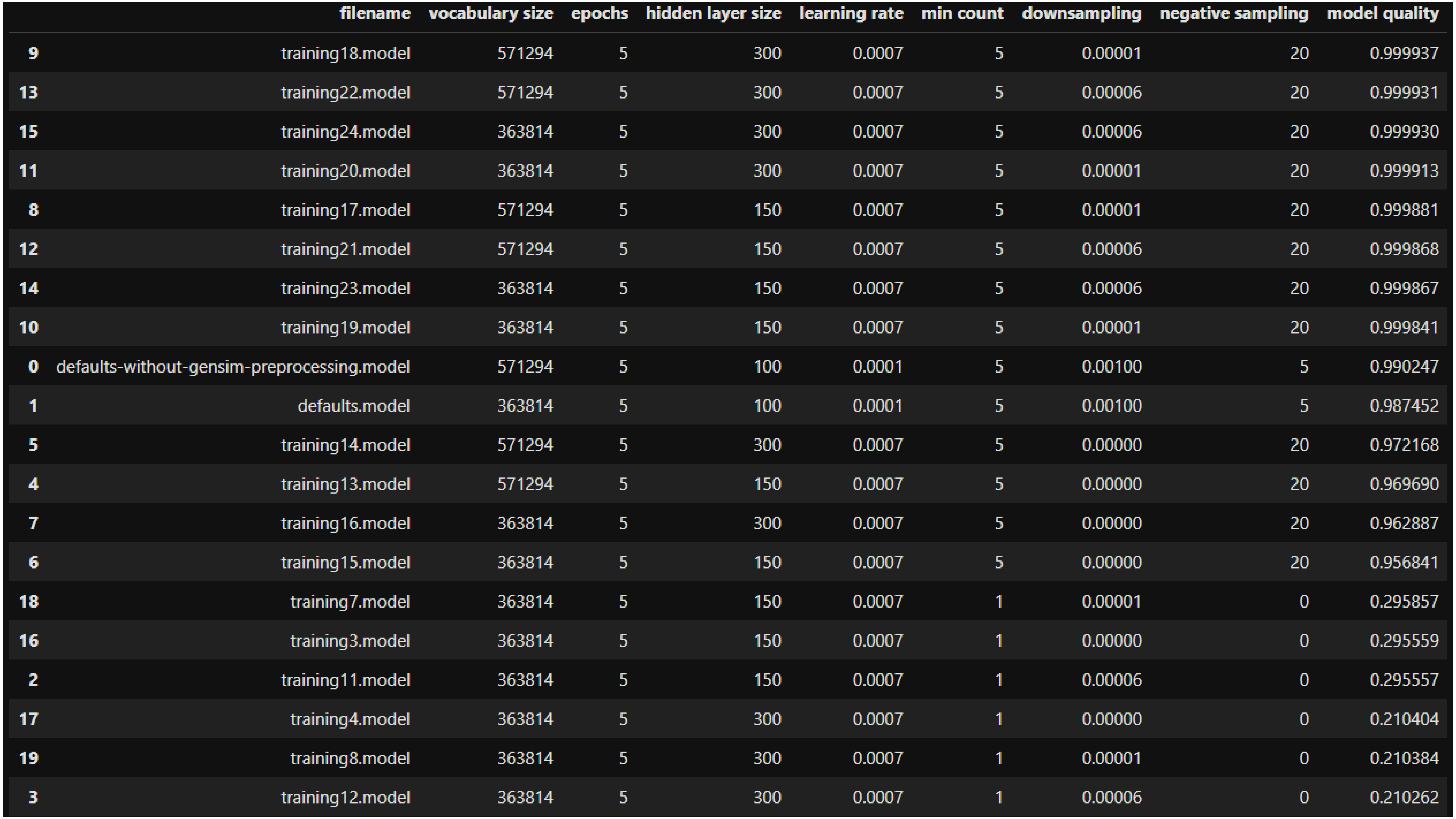
Example output – words similar to "Unemployment"

- Using t-SNE (distributed stochastic neighbor embedding) for dimensionality reduction
- Keywords are in English and German
- word2vec calculates similarity independent of language
- Blue keywords are similar, green keywords are not similar



Gutter search for optimizing word2vec parameters

- training gutter 2 * 3 * 2 * 2 = 24
  - size of matrix (using 150 or 300) = 2
  - sample (0, 1-e5, 6-e-5) = 3
  - using preprocessing (true or false) = 3
  - using mincout=5 and negative=20, or defaults = 2
- In addititition, default processing with or without gensim preprocessing
- Model quality overview – see next slide



	filename	vocabulary size	epochs	hidden layer size	learning rate	min count	downsampling	negative sampling	model quality
9	training18.model	571294	5	300	0.0007	5	0.00001	20	0.999937
13	training22.model	571294	5	300	0.0007	5	0.00006	20	0.999931
15	training24.model	363814	5	300	0.0007	5	0.00006	20	0.999930
11	training20.model	363814	5	300	0.0007	5	0.00001	20	0.999913
8	training17.model	571294	5	150	0.0007	5	0.00001	20	0.999881
12	training21.model	571294	5	150	0.0007	5	0.00006	20	0.999868
14	training23.model	363814	5	150	0.0007	5	0.00006	20	0.999867
10	training19.model	363814	5	150	0.0007	5	0.00001	20	0.999841
0	defaults-without-gensim-preprocessing.model	571294	5	100	0.0001	5	0.00100	5	0.990247
1	defaults.model	363814	5	100	0.0001	5	0.00100	5	0.987452
5	training14.model	571294	5	300	0.0007	5	0.00000	20	0.972168
4	training13.model	571294	5	150	0.0007	5	0.00000	20	0.969690
7	training16.model	363814	5	300	0.0007	5	0.00000	20	0.962887
6	training15.model	363814	5	150	0.0007	5	0.00000	20	0.956841
18	training7.model	363814	5	150	0.0007	1	0.00001	0	0.295857
16	training3.model	363814	5	150	0.0007	1	0.00000	0	0.295559
2	training11.model	363814	5	150	0.0007	1	0.00006	0	0.295557
17	training4.model	363814	5	300	0.0007	1	0.00000	0	0.210404
19	training8.model	363814	5	300	0.0007	1	0.00001	0	0.210384
3	training12.model	363814	5	300	0.0007	1	0.00006	0	0.210262

Issue with evalution

- No gold standard of word vectors for our input data is available
- Current evaluation calculates only the average of similarities scores for 10% of the vocabulary
  - E.g. for 363814 word = with 3638 words
- Future step: build evaluation vocabulary

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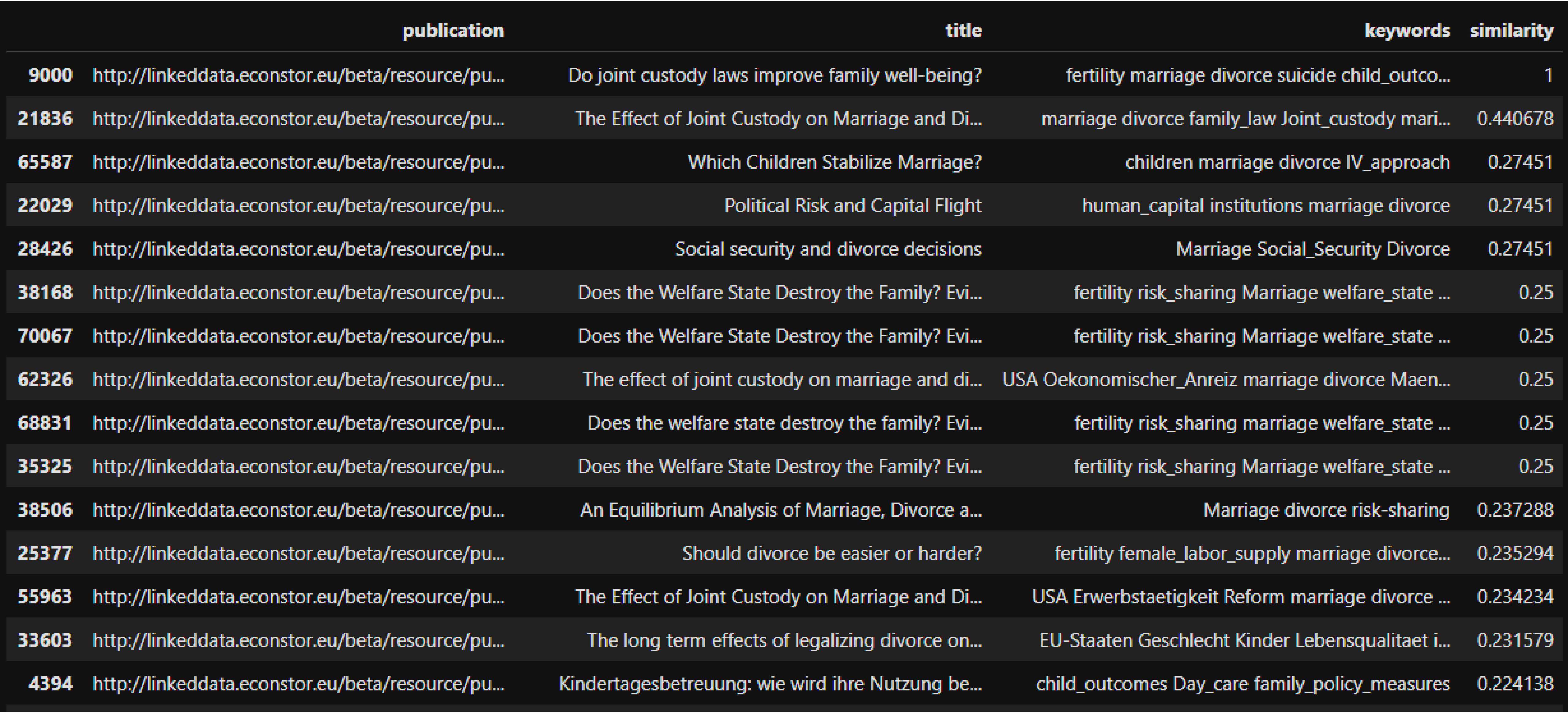
Application: recommender system

- Input: a document and its keywords
- Output: a list of similar documents
- Calculation of Jaccard similarity – first without word2vec: size of intersection divided by total size of set
  - doc 1: Germany labour
  - doc 2: Germany workforce
  - intersection = 1
  - total set = 3
  - Jaccard similarity = 1 / 3 = 0.33
- Recommendation approach: content-based filtering recommendation approach: given an input doc, ordering other document based on Jaccard similarity

Application: recommender system with word2vec

- Input: a document and its keywords
- Output: a list of similar documents
- Calculation of Jaccard similarity – with word2vec: size of intersection divided by total size of set
  - doc 1: Germany labour (workforce 0.9 similar to labour)
  - doc 2: Germany workforce
  - intersection = 2
  - total set = 3
  - Jaccard similarity = 2 / 3 = 0.666
- Example output (next slide)



	publication	title	keywords	similarity
9000	http://linkeddata.econstor.eu/beta/resource/pu...	Do joint custody laws improve family well-being?	fertility marriage divorce suicide child_outco...	1
21836	http://linkeddata.econstor.eu/beta/resource/pu...	The Effect of Joint Custody on Marriage and Di...	marriage divorce family_law Joint_custody mari...	0.440678
65587	http://linkeddata.econstor.eu/beta/resource/pu...	Which Children Stabilize Marriage?	children marriage divorce IV_approach	0.27451
22029	http://linkeddata.econstor.eu/beta/resource/pu...	Political Risk and Capital Flight	human_capital institutions marriage divorce	0.27451
28426	http://linkeddata.econstor.eu/beta/resource/pu...	Social security and divorce decisions	Marriage Social_Security Divorce	0.27451
38168	http://linkeddata.econstor.eu/beta/resource/pu...	Does the Welfare State Destroy the Family? Evi...	fertility risk_sharing Marriage welfare_state ...	0.25
70067	http://linkeddata.econstor.eu/beta/resource/pu...	Does the Welfare State Destroy the Family? Evi...	fertility risk_sharing Marriage welfare_state ...	0.25
62326	http://linkeddata.econstor.eu/beta/resource/pu...	The effect of joint custody on marriage and di...	USA Oekonomischer_Anreiz marriage divorce Maen...	0.25
68831	http://linkeddata.econstor.eu/beta/resource/pu...	Does the welfare state destroy the family? Evi...	fertility risk_sharing marriage welfare_state ...	0.25
35325	http://linkeddata.econstor.eu/beta/resource/pu...	Does the Welfare State Destroy the Family? Evi...	fertility risk_sharing Marriage welfare_state ...	0.25
38506	http://linkeddata.econstor.eu/beta/resource/pu...	An Equilibrium Analysis of Marriage, Divorce a...	Marriage divorce risk-sharing	0.237288
25377	http://linkeddata.econstor.eu/beta/resource/pu...	Should divorce be easier or harder?	fertility female_labor_supply marriage divorce...	0.235294
55963	http://linkeddata.econstor.eu/beta/resource/pu...	The Effect of Joint Custody on Marriage and Di...	USA Erwerbstaetigkeit Reform marriage divorce ...	0.234234
33603	http://linkeddata.econstor.eu/beta/resource/pu...	The long term effects of legalizing divorce on...	EU-Staaten Geschlecht Kinder Lebensqualitaet i...	0.231579
4394	http://linkeddata.econstor.eu/beta/resource/pu...	Kindertagesbetreuung: wie wird ihre Nutzung be...	child_outcomes Day_care family_policy_measures	0.224138

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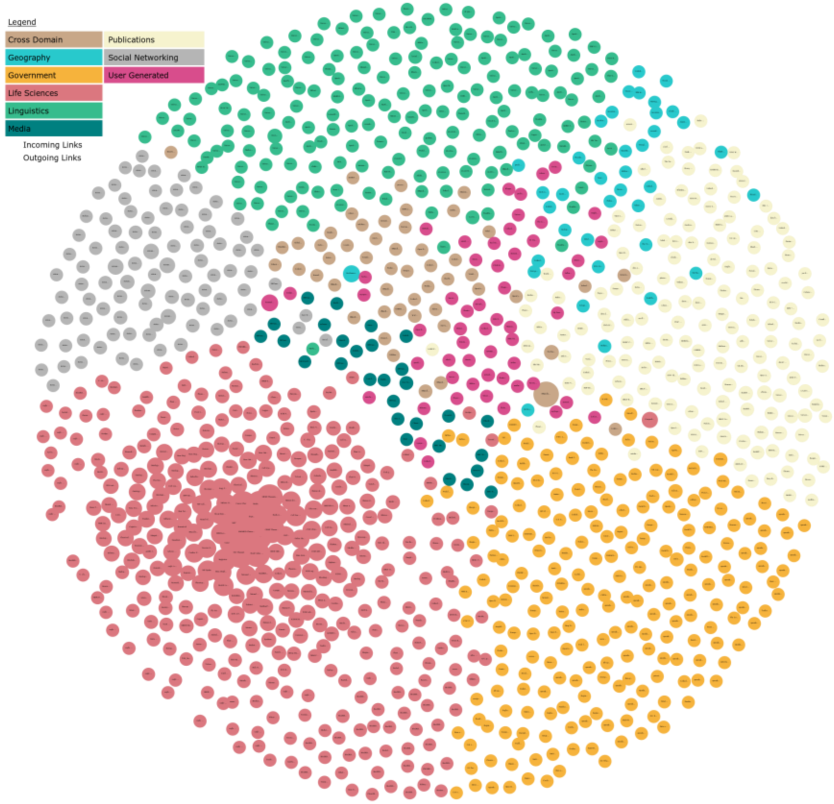
Open questions

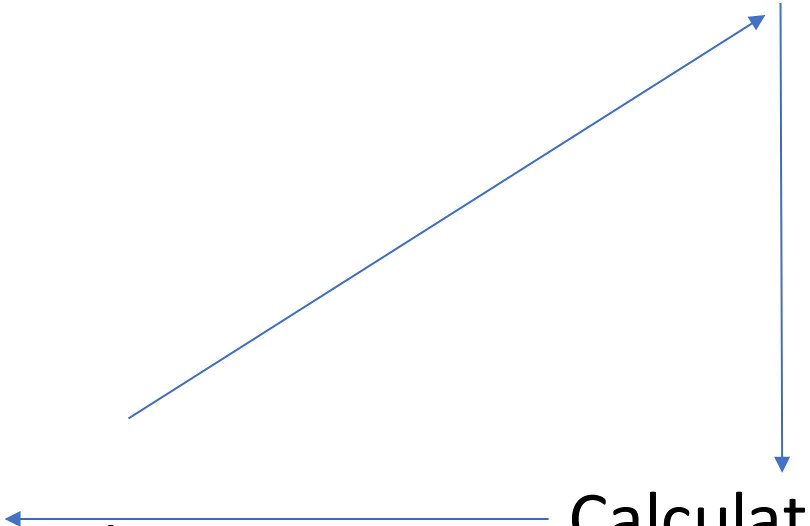
- Dealing with rare keywords
  - word2vec drops several words
  - Gutter search shows that keeping all words leads to lower quality of the model
  - An approach for rare words is needed
- Evaluating the model
  - Build samples, use perplexity for evaluation
  - Compare e.g. to doc2vec based processing and tf-idf
- Using existing models and disambiguation
  - E.g. Google BERT provides pre-trained models to use disambiguation
    - E.g. German “Bank” from Bank”
  - Fine-tuning of models like BERT could be a basis for implementing disambiguation
- Using the similarities to enhance the linked open data sources – **building a circle between linked data and machine learning**

Motivation – from the perspective of applied computational linguistics research

Linked (open) data sources



Input to machine learning



Calculation of data similarities

Enhancement of data models

Word2Vec and Metadata Records

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April 2019