Integrating News Article Metadata into Topic Models

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Agenda

Query Generation

Introduction

Information Retrieval Methods

Experiment

Results

Conclusion

Language Model
Information retrieval goal

- We want to find relevant documents based on words in a query

$$P(q|d) = \prod_{w \in q} P(w|d)$$

Language Model
Explanation

$$P(w|d) = \frac{N_d}{N_d + \lambda} \cdot \frac{tf(w,d)}{N_d} + (1 - \frac{N_d}{N_d + \lambda}) \cdot \frac{tf(w,D)}{N_D}$$

- d = document
- N_d = Number of words in d
- λ is the average document length
- D = Corpus

Language Model
Explanation

$$P(w|d) = \underbrace{\frac{N_d}{N_d + \lambda}}_{\text{weight term}} \cdot \frac{tf(w,d)}{N_d} + \underbrace{(1 - \frac{N_d}{N_d + \lambda})}_{\text{inverse weight term}} \cdot \frac{tf(w,D)}{N_D}$$

- d = document
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Explanation

$$P(w|d) = \underbrace{\frac{N_d}{N_d + \lambda}}_{\text{weight term}} \cdot \underbrace{\frac{tf(w,d)}{N_d}}_{\text{\% of w in d}} + \underbrace{(1 - \frac{N_d}{N_d + \lambda})}_{\text{inverse weight term}} \cdot \underbrace{\frac{tf(w,D)}{N_D}}_{\text{\% w in D}}$$

- d = document
- N_d = Number of words in d
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Language Model
Explanation

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- d = document
- N_d = Number of words in d
- λ is the average document length
- D = Corpus

Language Model
Explanation

- Favors high percentage of a word in a document or corpus

TF-IDF
Explanation

$$\text{tf-idf}(t, d, D) = \text{tf}(t, d) \cdot \text{idf}(t, D)$$

- t = Term
- d = Document
- D = Corpus

TF-IDF
Explanation

$$\text{tf-idf}(t, d, D) = \text{tf}(t, d) \cdot log \frac{|\{d \in D\}|}{|\{d \in D : t \in d\}|}$$

TF-IDF
Summary

- Favors high usage of unique word(s) in a document or corpus

BM25
Explanation

$$\text{bm25}(d, q) = \sum_{i=1}^{n} \text{idf}(q_i) \cdot \frac{\text{tf}(q_i, d) \cdot (k_1 + 1)}{\text{tf}(q_i, d) + k_1 \cdot (1 - b + b \cdot \frac{|d|}{avgdl})}$$

- b adjust the sensitivity of varying document lengths
- k_1 adjust how quickly a term is saturated

BM25
Explanation

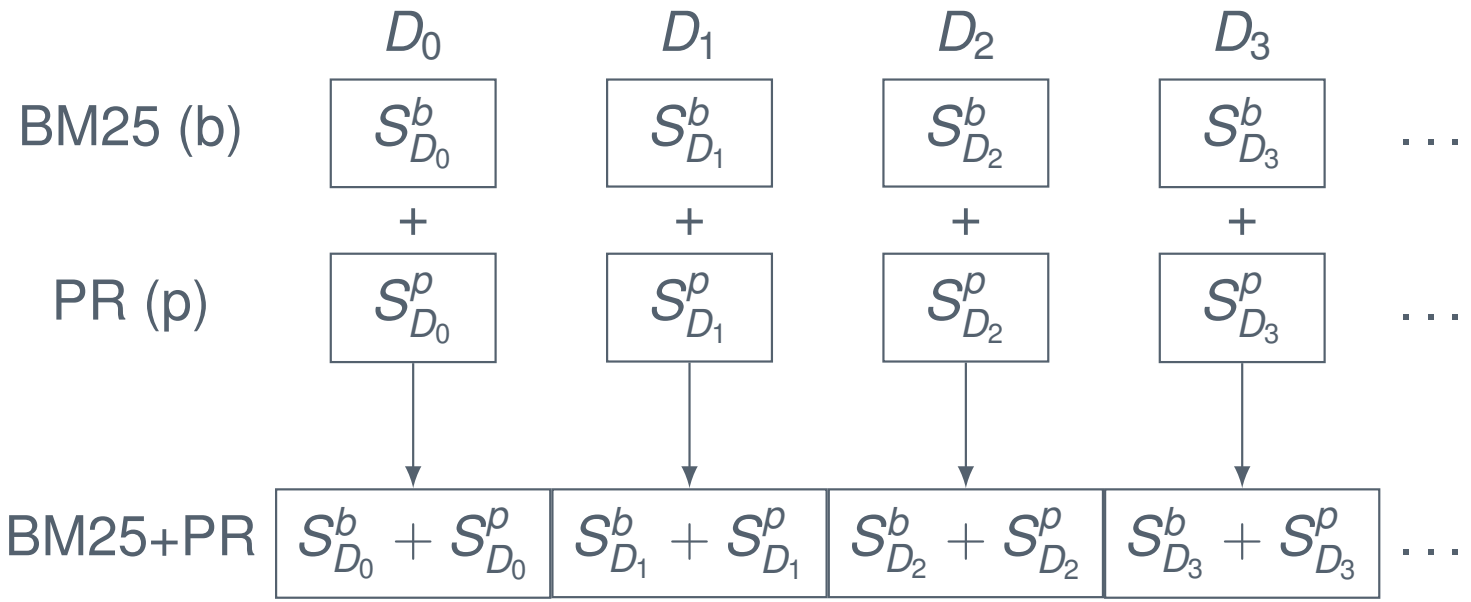
$$\text{bm25}(d, q) = \sum_{i=1}^{n} \text{idf}(q_i) \cdot \frac{\text{tf}(q_i, d) \cdot (1.5 + 1)}{\text{tf}(q_i, d) + 1.5 \cdot (1 - 0.75 + 0.75 \cdot \frac{|d|}{avgdl})}$$

BM25
Summary

- Similar to tf-idf but with some other focus points
  - Document length
  - Word saturation

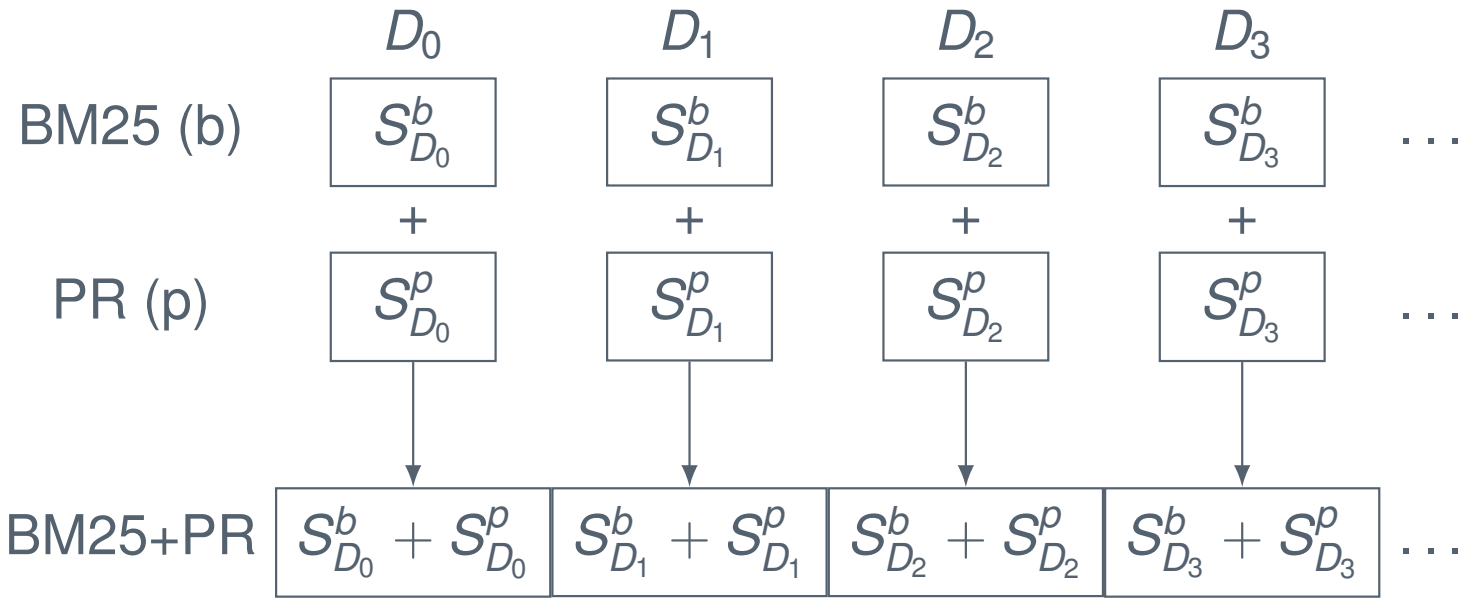
Combination of methods

How to combine?



Combination of methods

How to combine?



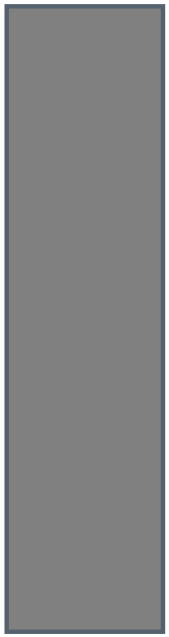
- $t \cdot A + (1 - t) \cdot B$

Query Generation
Types of queries

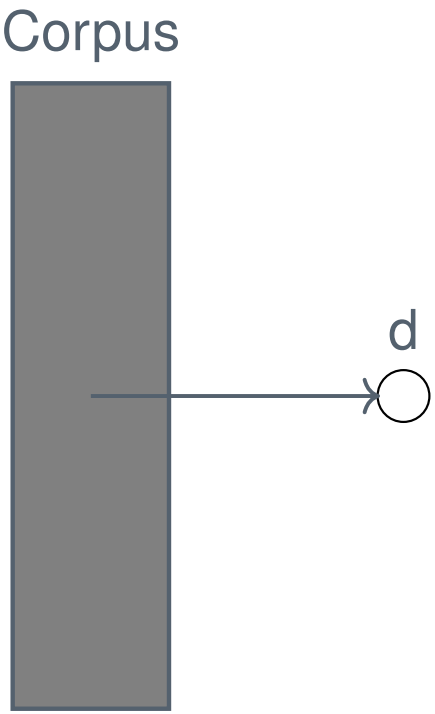
- Document query
  - Specificity - Finding a specific document
- Topic query
  - Generality - Finding topic relevant documents

Document Query
Generation

Corpus



Document Query
Generation



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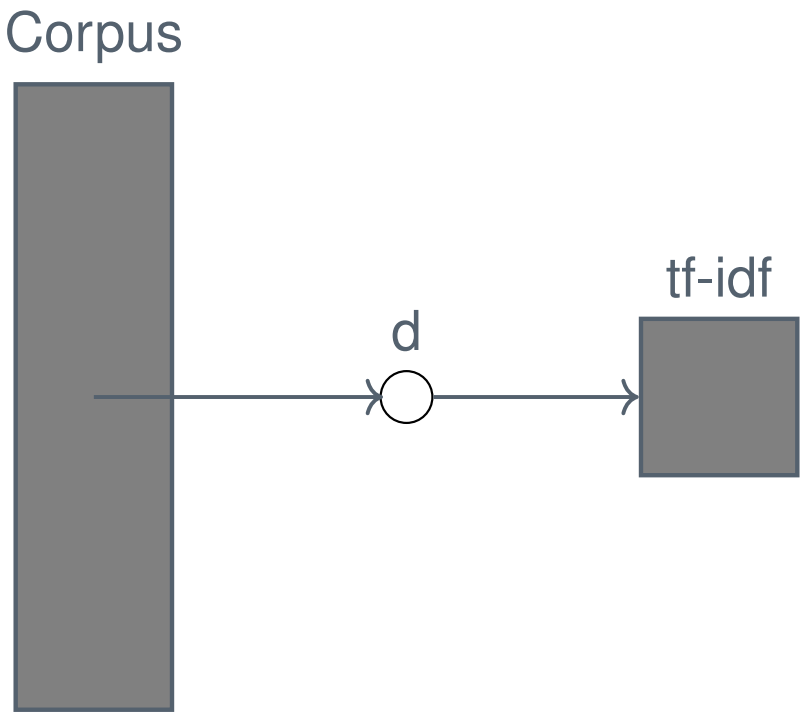

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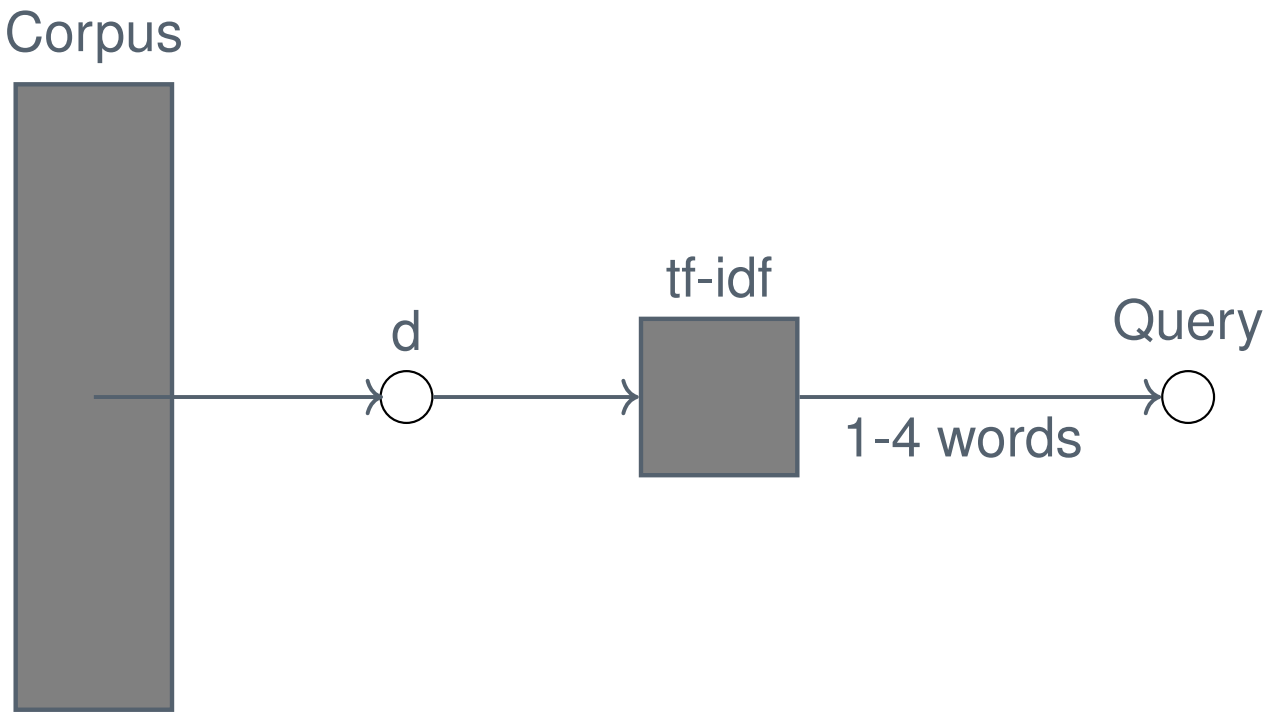

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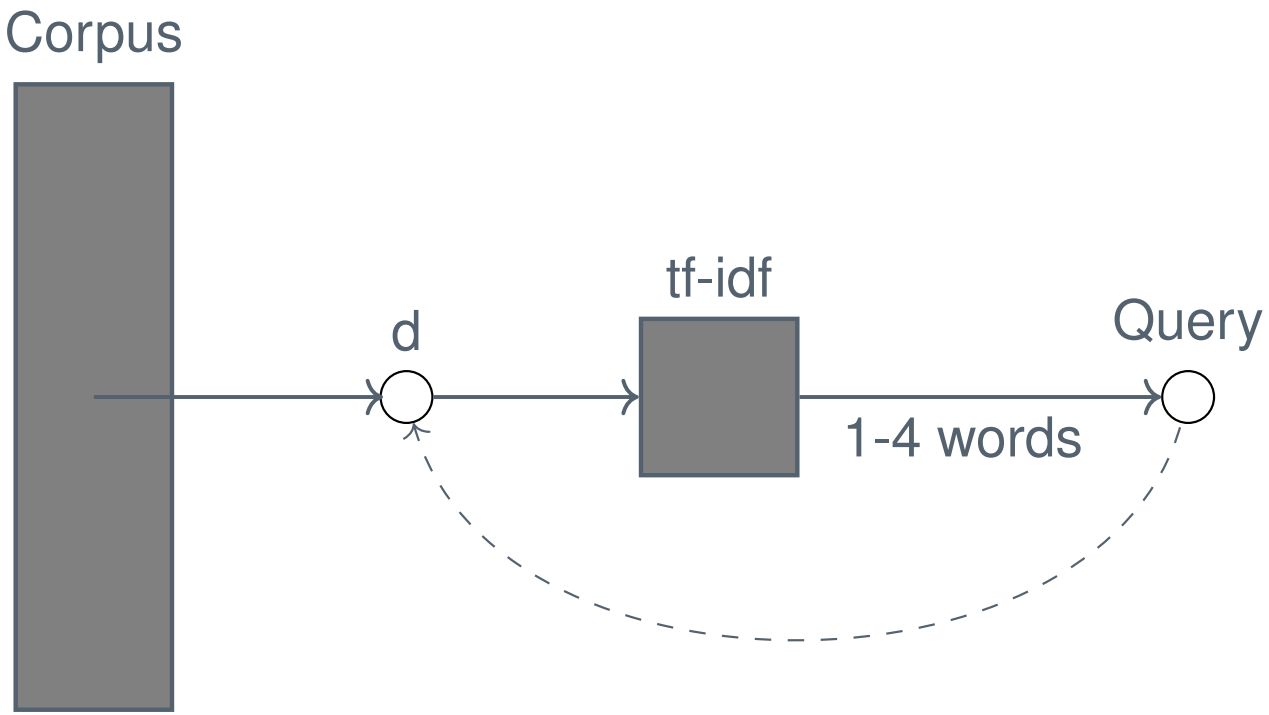
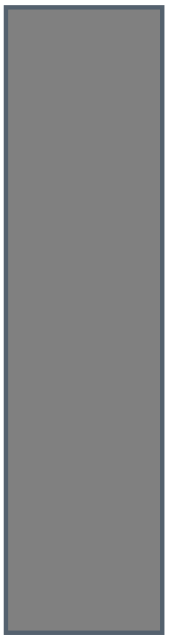
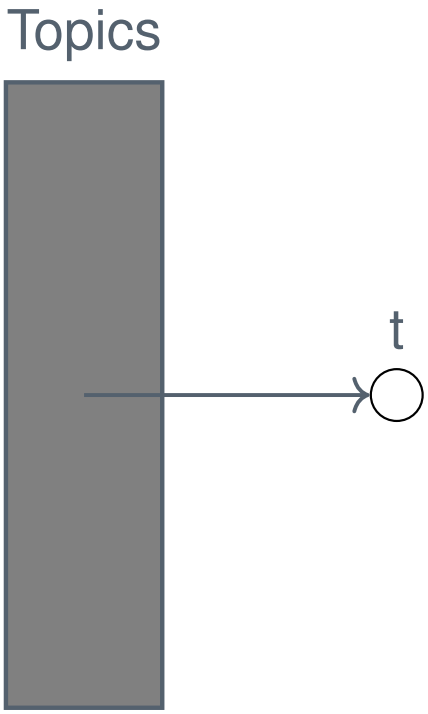


Topic Query
Generation

Topics



Topic Query
Generation



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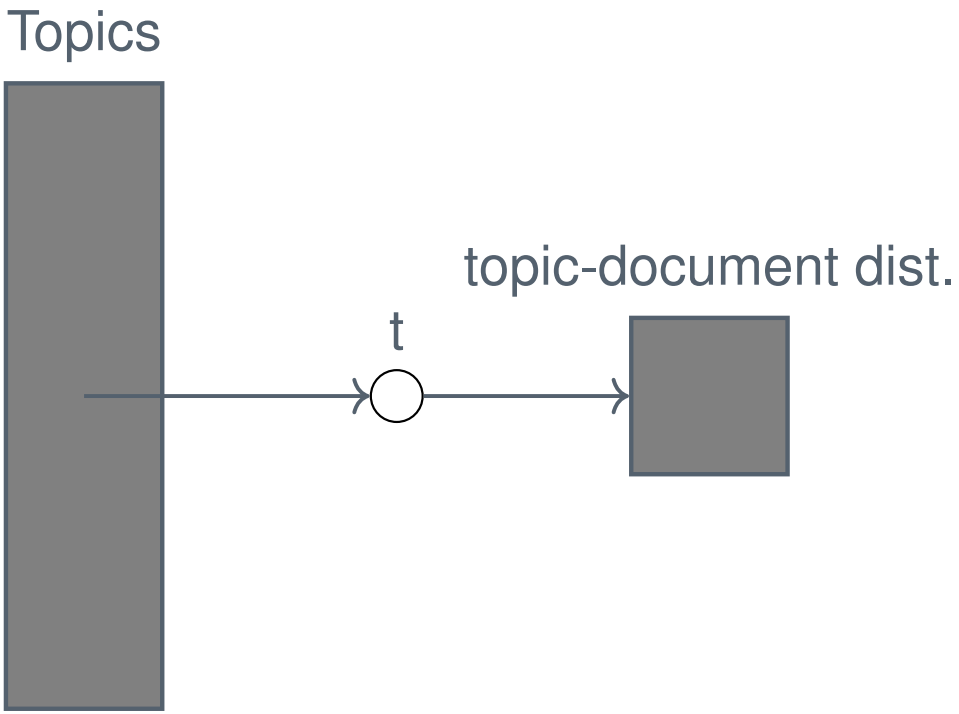

Topic Query
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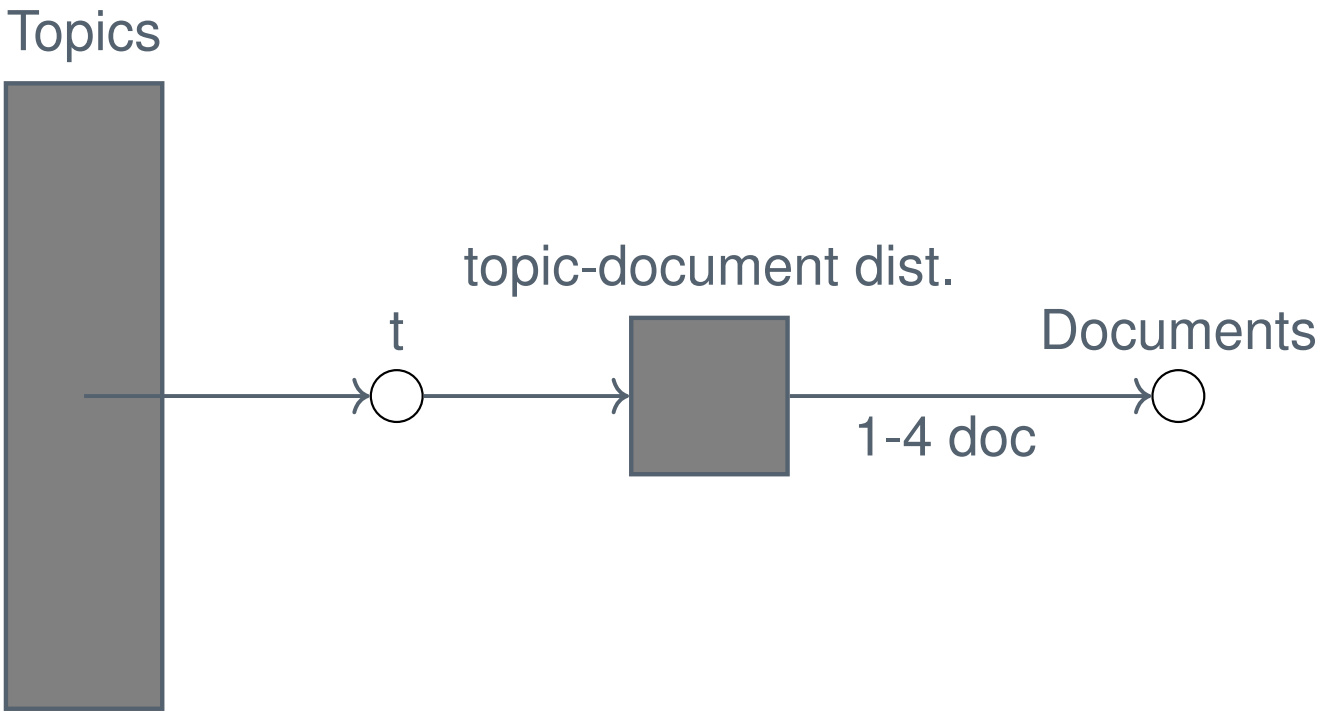

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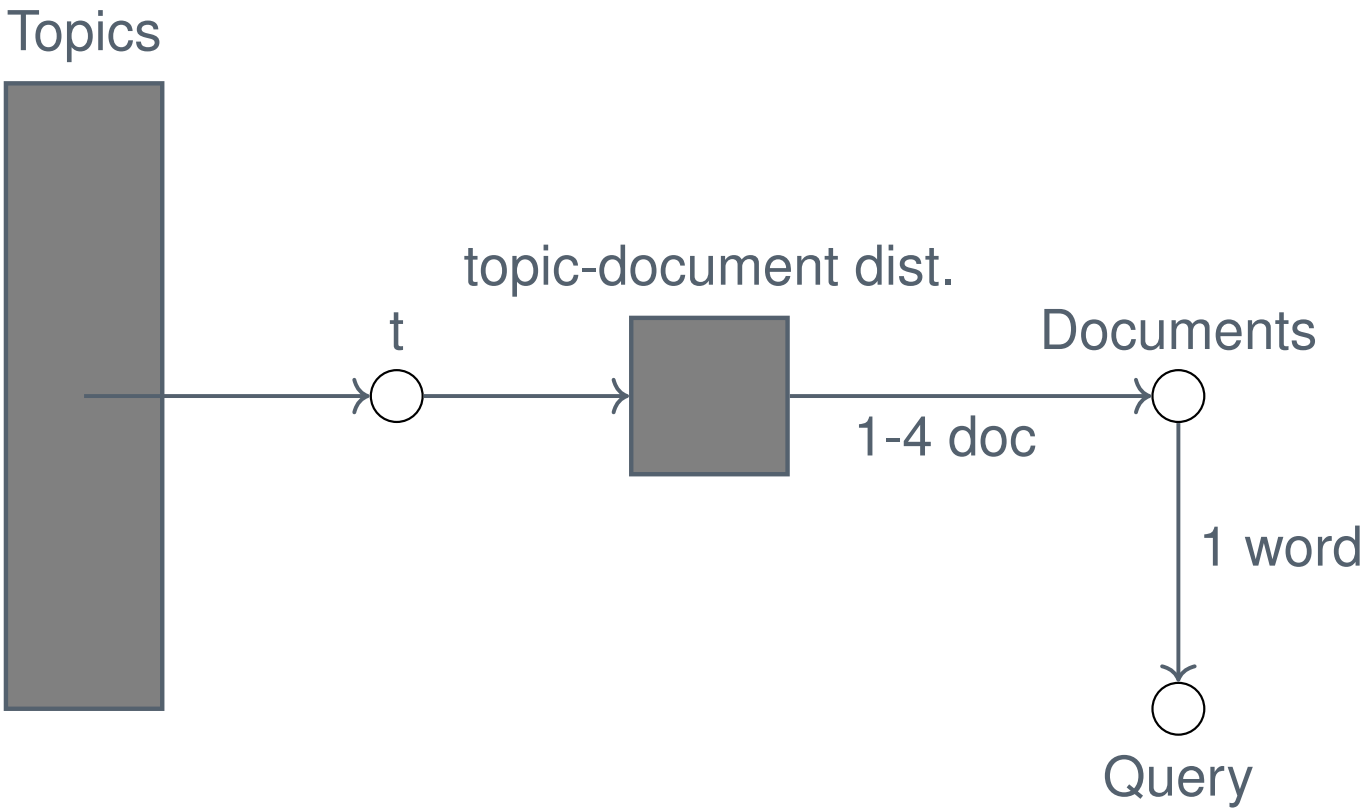

Topic Query
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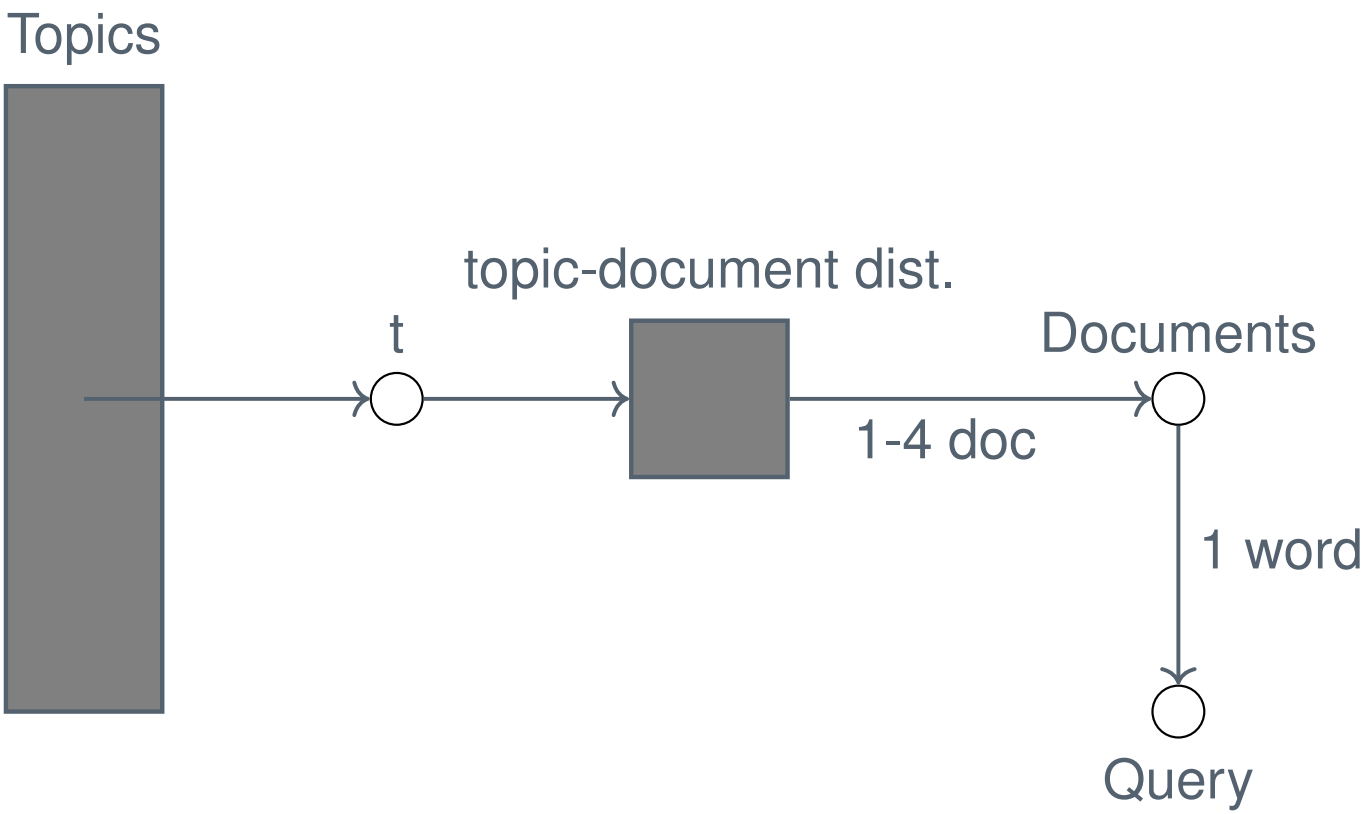


- Sample the topic-word distribution instead

Introduction
Motivation

- Query based search of documents
  - Google Scholar
- Encourage abstractions of underlying topics
  - Rather than word frequency

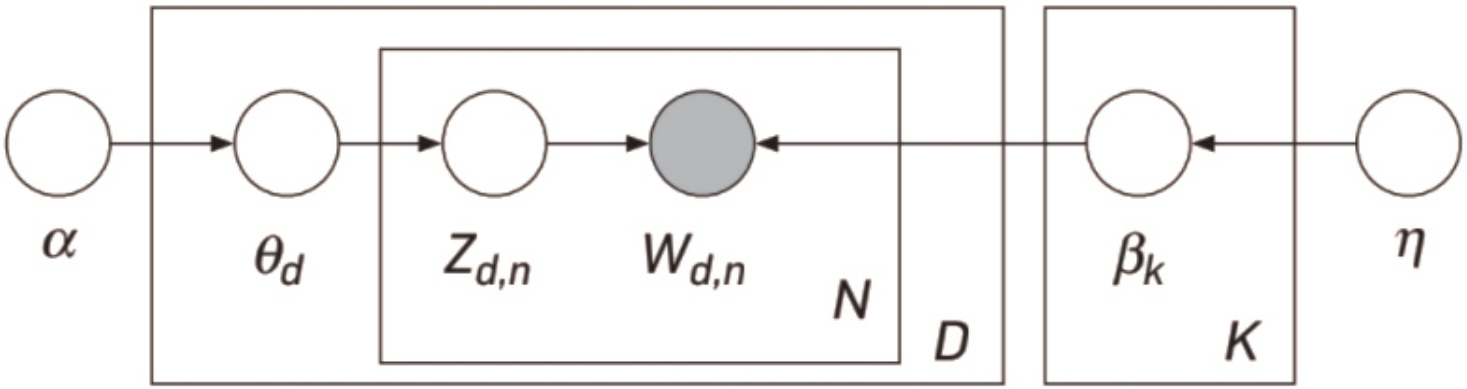
Information Retrieval Methods

- Latent Dirichlet Allocation (LDA)
- PageRank (PR)
- Language Model (LM)
- Term Frequency - Inverse Document Frequency (TF-IDF)
- Best Match 25 (BM25)

Latent Dirichlet Allocation
Motivation

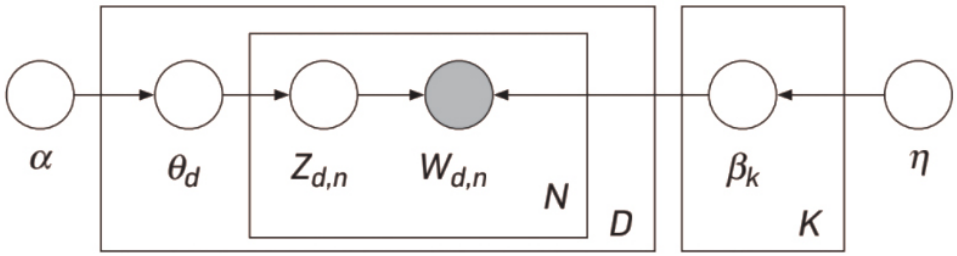
- Create a generative process to produce documents, based on topics
- Fine-tune to maximize probability of generating the original documents
- Use generated topics for calculating similarity

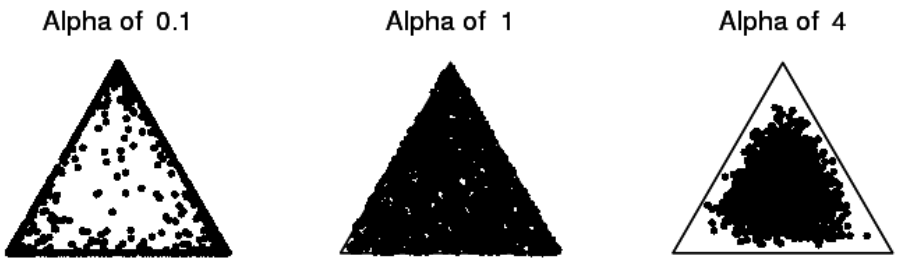
Latent Dirichlet Allocation
Plate Notation



- α, η dirichlet distributions
- θ, β multinomial distributions
- Z, W sampled topics and words

Latent Dirichlet Allocation
Dirichlet Distributions





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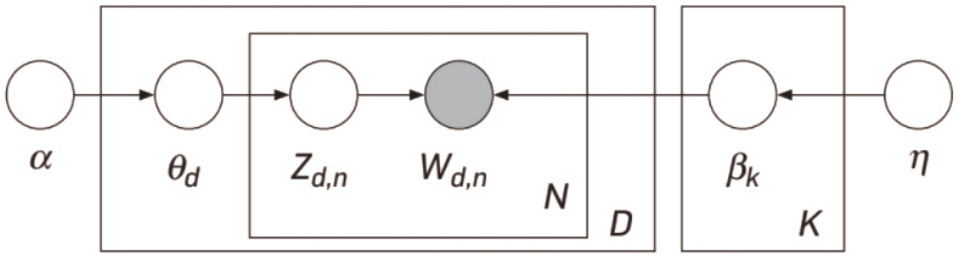
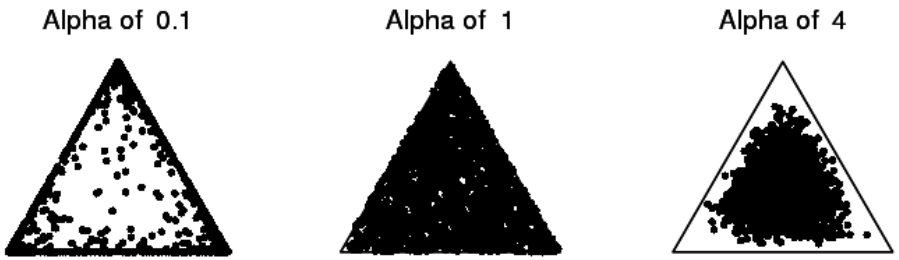
[1] https://mollermara.com/blog/lda/

Latent Dirichlet Allocation
Dirichlet Distributions



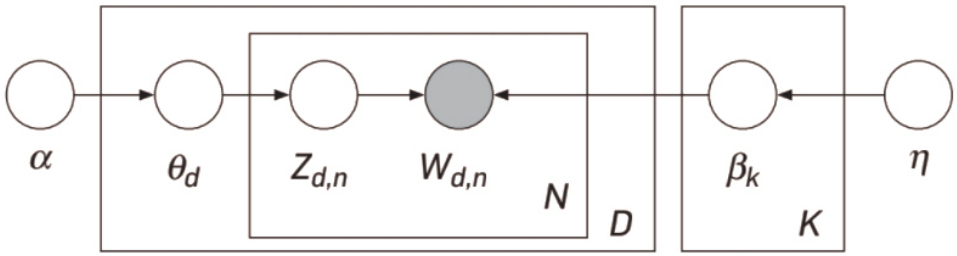


[1]

- typical sample based on low alpha = $\{1, 0, 0\}$
- typical sample based on high alpha = $\{0.333, 0.333, 0.333\}$

[1] https://mollermara.com/blog/lda/

Latent Dirichlet Allocation
Multinomial Distributions



- Sample N topics (Z) based on θ
- Sample N words (W) based on Z and β

Latent Dirichlet Allocation
Generation Probability

$$P(W, Z, \theta, \beta; \alpha, \eta) =$$
$$\prod_{d=1}^{D} P(\theta_d; \alpha) \prod_{k=1}^{K} P(\beta_k; \eta) \prod_{n=1}^{N} P(Z_{d,n}|\theta_d) P(W_{d,n}|\beta, Z_{d,n})$$

PageRank
Overview

- Used to rank nodes in a graph
- Underlying assumption: important nodes have in-going connections from other important nodes
- Based on the 'random surfer' model

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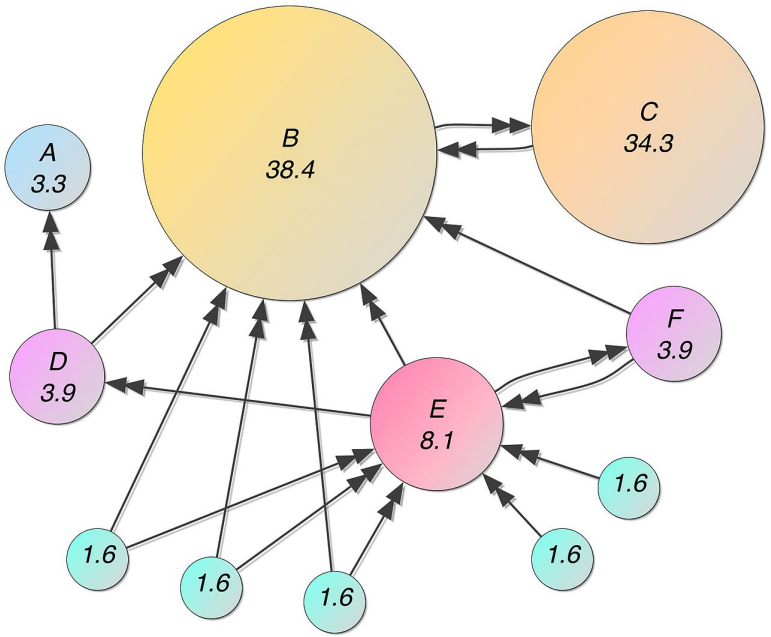

[2]

[2] https://en.wikipedia.org/wiki/PageRank

PageRank
Graph Construction

- Used on adjacency matrix
- Similarity between documents based on θ
  - Calculated using Jensen-Shannon similarity
- While fully connected each edge has a value which will influence the ranking

Grid-search

Parameter	Tested Values
K_1	10, 50, 100, 200, 300
K_2	5, 10, 15, 20, 25, 30, 35, 40, 45, 50
α	0.5, 0.1, 0.01, 0.001
η	0.1, 0.01, 0.001, 0.0001

Grid-search

Parameter	Tested Values
K_1	**10**, **50**, 100, 200, 300
K_2	5, 10, 15, 20, 25, 30, 35, 40, 45, 50
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Grid-search

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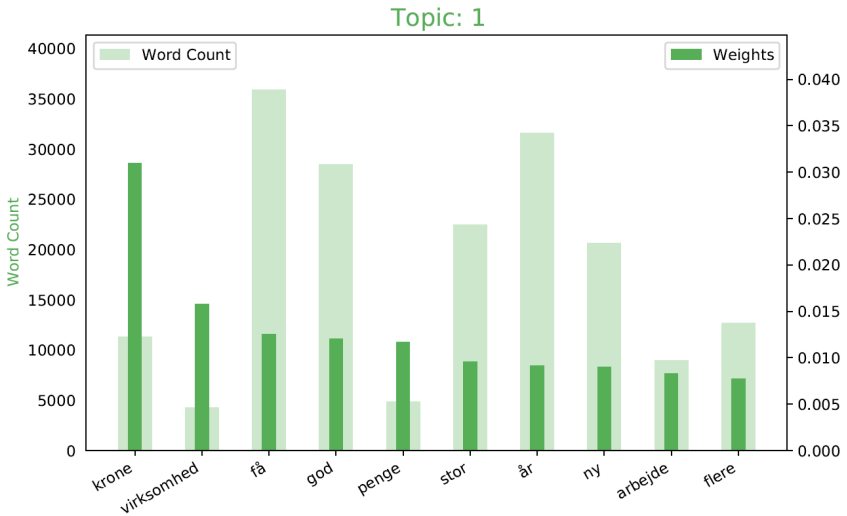

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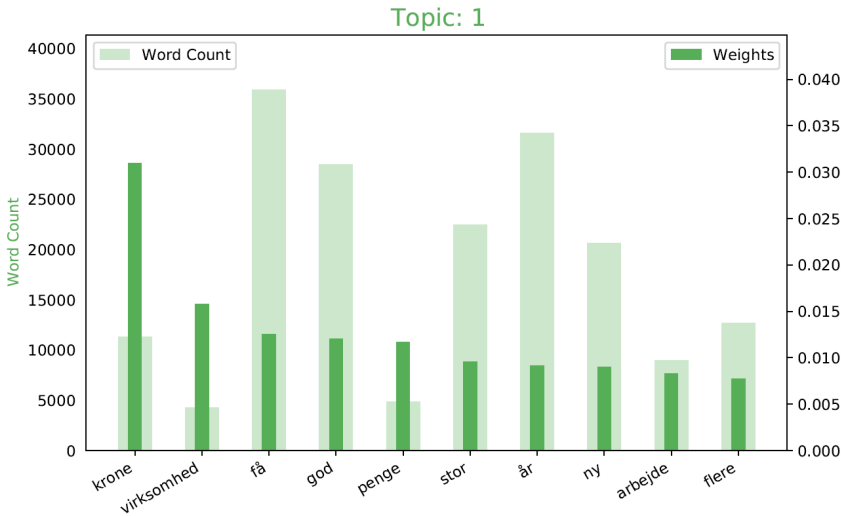

- $K = 30$, $\alpha = 0.1$, and $\eta = 0.1$

Mean Average Precision Results

IR methods / MAP	Document Query Length 1	2	3	4	Topic Query Length 1	2	3	4
LDA-IR	0.00457	0.00527	0.0429	0.0538	0.155	0.186	0.168	0.178
LM	0.198	0.152	0.291	0.260	0.126	0.130	0.128	0.129
BM25	0.270	0.656	0.866	**0.908**	0.155	0.158	0.155	0.161
tf-idf	0.210	0.621	0.799	0.897	0.155	0.157	0.155	0.161
LDA-IR + PR	0.00458	0.00526	0.0429	0.0538	0.162	**0.195**	**0.177**	**0.187**
LDA-IR * PR	0.00781	0.00569	0.0410	0.0537	0.156	0.186	0.168	0.179
LM + LDA-IR	0.0419	0.0214	0.0602	0.120	0.147	0.163	0.145	0.146
LM * LDA-IR	0.0931	0.0462	0.175	0.177	0.150	0.175	0.155	0.166
LM + PR	0.170	0.153	0.283	0.256	0.130	0.132	0.130	0.131
LM * PR	0.163	0.138	0.259	0.236	0.130	0.133	0.129	0.130
LM + LDA-IR + PR	0.0499	0.0214	0.0601	0.120	0.148	0.164	0.146	0.147
LM * LDA-IR * PR	0.0911	0.0459	0.157	0.170	0.150	0.175	0.155	0.166
BM25 + LDA-IR	**0.276**	0.524	0.588	0.365	0.155	0.184	0.168	0.176
BM25 * LDA-IR	0.139	0.270	0.412	0.365	0.154	0.159	0.156	0.162
BM25 + PR	0.269	0.656	0.866	0.902	**0.192**	0.193	0.175	0.183
BM25 * PR	0.267	**0.663**	**0.884**	0.904	0.155	0.159	0.155	0.161
BM25 + LDA-IR + PR	**0.276**	0.525	0.589	0.366	0.162	0.192	0.176	0.184
BM25 * LDA-IR * PR	0.150	0.266	0.446	0.381	0.155	0.159	0.156	0.163

Results

Precision Results

IR methods	Topic Query Length (P@10) 1	2	3	4	Topic Query Length (P@100) 1	2	3	4
LDA-IR	0.02	0.103	0.13	0.203	0.062	0.131	0.164	0.191
LM	0.126	0.118	0.116	0.069	0.090	0.092	0.087	0.093
BM25	0.136	0.161	0.164	0.174	0.142	0.165	0.175	0.151
tf-idf	0.160	0.125	**0.200**	0.148	**0.163**	0.169	**0.188**	0.170
LDA-IR + PR	0.0188	0.103	0.141	**0.211**	0.062	0.131	0.175	**0.198**
LDA-IR * PR	0.0125	0.100	0.133	0.200	0.062	0.132	0.167	0.192
LM + LDA-IR	0.02	0.101	0.136	0.196	0.060	0.129	0.161	0.188
LM * LDA-IR	0.02	0.085	0.109	0.161	0.055	0.114	0.129	0.152
LM + PR	0.138	0.130	0.116	0.0763	0.110	0.108	0.097	0.098
LM * PR	0.148	0.128	0.116	0.0963	0.110	0.112	0.101	0.101
LM + LDA-IR + PR	0.019	0.101	0.134	0.195	0.061	0.129	0.163	0.187
LM * LDA-IR * PR	0.026	0.090	0.110	0.161	0.059	0.115	0.130	0.152
BM25 + LDA-IR	0.124	0.160	0.154	0.204	0.113	0.155	0.168	**0.198**
BM25 * LDA-IR	0.09	0.139	0.175	0.206	0.134	0.170	0.174	0.187
BM25 + PR	0.135	0.163	0.165	0.173	0.155	0.165	0.176	0.151
BM25 * PR	**0.165**	**0.169**	0.184	0.170	0.148	**0.177**	0.186	0.161
BM25 + LDA-IR + PR	0.124	0.160	0.154	0.204	0.113	0.155	0.17	**0.198**
BM25 * LDA-IR * PR	0.095	0.141	0.176	0.206	0.135	0.174	0.174	0.188

Results

Average Rank Results

IR methods / Avg. Rank	Document Query Length 1	2	3	4
LDA-IR	2287.93	1599.95	1241.18	1926.78
LM	7120.04	9082.9	6501.85	7782.65
BM25	**19.58**	7.94	1.78	1.41
tf-idf	30.0	9.3	2.03	1.29
LDA-IR + PR	2491.31	1342.53	1126.23	1906.76
LDA-IR * PR	2305.04	1600.93	1223.14	1920.175
LM + LDA-IR	1971.19	1192.91	1027.95	1482.69
LM * LDA-IR	1874.81	1456.21	954.66	1853.44
LM + PR	7299.85	9134.81	6429.24	7725.36
LM * PR	7328.7625	9137.23	6504.85	7772.4
LM + LDA-IR + PR	1978.74	1179.21	994.91	1438.88
LM * LDA-IR * PR	1892.12	1453.56	941.4	1850.43
BM25 + LDA-IR	30.45	28.59	17.7	23.76
BM25 * LDA-IR	163.76	557.13	297.48	1159.33
BM25 + PR	19.69	**7.88**	1.79	1.43
BM25 * PR	23.96	8.45	**1.61**	**1.24**
BM25 + LDA-IR + PR	30.35	28.44	17.65	23.76
BM25 * LDA-IR * PR	163.5	555.35	295.69	1158.08

MAP Random Document Results

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Random	0.000357				0.144			

Precision Random Document Results

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LM	0.126	0.118	0.116	0.069	0.090	0.092	0.087	0.093
BM25	0.136	0.161	0.164	0.174	0.142	0.165	0.175	0.151
tf-idf	0.160	0.125	**0.200**	0.148	**0.163**	0.169	**0.188**	0.170
LDA-IR + PR	0.0188	0.103	0.141	**0.211**	0.062	0.131	0.175	**0.198**
LDA-IR * PR	0.0125	0.100	0.133	0.200	0.062	0.132	0.167	0.192
LM + LDA-IR	0.02	0.101	0.136	0.196	0.060	0.129	0.161	0.188
LM * LDA-IR	0.02	0.085	0.109	0.161	0.055	0.114	0.129	0.152
LM + PR	0.138	0.130	0.116	0.0763	0.110	0.108	0.097	0.098
LM * PR	0.148	0.128	0.116	0.0963	0.110	0.112	0.101	0.101
LM + LDA-IR + PR	0.019	0.101	0.134	0.195	0.061	0.129	0.163	0.187
LM * LDA-IR * PR	0.026	0.090	0.110	0.161	0.059	0.115	0.130	0.152
BM25 + LDA-IR	0.124	0.160	0.154	0.204	0.113	0.155	0.168	**0.198**
BM25 * LDA-IR	0.09	0.139	0.175	0.206	0.134	0.170	0.174	0.187
BM25 + PR	0.135	0.163	0.165	0.173	0.155	0.165	0.176	0.151
BM25 * PR	**0.165**	**0.169**	0.184	0.170	0.148	**0.177**	0.186	0.161
BM25 + LDA-IR + PR	0.124	0.160	0.154	0.204	0.113	0.155	0.17	**0.198**
BM25 * LDA-IR * PR	0.095	0.141	0.176	0.206	0.135	0.174	0.174	0.188
Random	0.142				0.152			

Average Rank Random Document Results

IR methods / Avg. Rank	Document Query Length 1	2	3	4
LDA-IR	2287.93	1599.95	1241.18	1926.78
LM	7120.04	9082.9	6501.85	7782.65
BM25	**19.58**	7.94	1.78	1.41
tf-idf	30.0	9.3	2.03	1.29
LDA-IR + PR	2491.31	1342.53	1126.23	1906.76
LDA-IR * PR	2305.04	1600.93	1223.14	1920.175
LM + LDA-IR	1971.19	1192.91	1027.95	1482.69
LM * LDA-IR	1874.81	1456.21	954.66	1853.44
LM + PR	7299.85	9134.81	6429.24	7725.36
LM * PR	7328.7625	9137.23	6504.85	7772.4
LM + LDA-IR + PR	1978.74	1179.21	994.91	1438.88
LM * LDA-IR * PR	1892.12	1453.56	941.4	1850.43
BM25 + LDA-IR	30.45	28.59	17.7	23.76
BM25 * LDA-IR	163.76	557.13	297.48	1159.33
BM25 + PR	19.69	**7.88**	1.79	1.43
BM25 * PR	23.96	8.45	**1.61**	**1.24**
BM25 + LDA-IR + PR	30.35	28.44	17.65	23.76
BM25 * LDA-IR * PR	163.5	555.35	295.69	1158.08
Random	16080			

Self-made Query

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  - Debate about EU and converting to green energy

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- Article 17717 is also about green growth and protecting the environment

Conclusion

- *How can we generate queries for a dataset to use for IR?*
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  - Creating the PR adjacency matrix using the similarity between document topic distributions
  - Highly effective

Thank you

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