Retrieval Enhancements for Task-Based Web Search

The Oral Exam of
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To Obtain the Academic Degree of
Dr. rer. nat.

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Bauhaus-Universität Weimar

www.uni-weimar.de   www.webis.de
Retrieval Enhancements for Task-Based Web Search

Outline

1. Task-based Search

2. Contribution 1: Writing Tasks

3. Contribution 2: Axiomatic Result Reranking

4. Summary
Retrieval Enhancements for Task-Based Web Search

The Task-Based Web Search Process

Diagram:

1. User
   - Identify Information Need
   - Submit Query
   - Select Results
   - Exploit Results
   - Task complete?

2. System
   - Rank Results
   - Build Result Page

Retrieval Enhancements for Task-Based Web Search

The Task-Based Web Search Process
Contributions

User-oriented

System-oriented
Retrieval Enhancements for Task-Based Web Search

Contributions

User-oriented

- Understanding and Supporting Writing Tasks
  - [Potthast, Hagen, Völske, Stein; ACL 2013]
  - [Potthast, Hagen, Völske, Stein; EuroHCIR 2013]
  - [Hagen, Potthast, Völske, Stein; CHIIR 2016]
  - [Vakkari, Völske, Hagen, Potthast, Stein; TPDL 2018]
  - [Vakkari, Völske, Potthast, Hagen, Stein; IP&M 2019]

- Result Presentation for Exploratory Search
  - [Gollub, Völske, Hagen, Stein; JCDL 2014]
  - [Völske, Gollub, Hagen, Stein; WOSP 2014]

- Query-Task Mapping
  - [Völske, Fatehifar, Stein, Hagen; SIGIR 2019]

- Automatic Summarization
  - [Völske, Potthast, Syed, Stein; NewSum 2017]
  - [Syed, Völske, Potthast, Lipka, Stein, Schütze; INLG 2018]

System-oriented

- Categorizing Question Queries
  - [Völske, Braslavski, Hagen, Lezina, Stein; CIKM 2015]

- Axiomatic Result Reranking
  - [Hagen, Völske, Göring, Stein; CIKM 2016]
Retrieval Enhancements for Task-Based Web Search

Contributions

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Understanding and Supporting Writing Tasks
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System-oriented

Axiomatic Result Reranking
- Hagen, Völske, Göring, Stein; CIKM 2016
Contribution 1:
Understanding and Supporting Writing Tasks
1. How do authors interact with search engines during complex writing tasks?

2. What are implications for search engine design?
The Webis-TRC-12 Dataset

TREC Topics (150)

ClueWeb09

Authors (12)

Search Engine

Interaction Log

Revision Log

Editor

10 Retrieval Enhancements for Task-Based Web Search © Völske 2019
Writing and Search Behavior
Essay Writing Visualization

Query, result browsing
Result click, reading
Writing session
Short pause
Essay length (relative)

1 hour and 100% final essay length
2 hours and 200% final essay length

day 1
day 2
day 3
day 4

Topic 27
Topic 57

100% final essay length
200% final essay length

1 hour and 2 hours and
Boil-down Strategy
Two working phases:
1. Gather Material
2. Write text
Boil-down Strategy
Two working phases:
1. Gather Material
2. Write text

Build-Up Strategy
1. Gather Source
2. Integrate
3. Repeat
Writing and Search Behavior

Authors are Quite Consistent!

![Graph showing writing and search behavior patterns.](chart.png)
Writing and Search Behavior

Authors are Quite Consistent!

“Boil-down”

“Build-up”

Percentage of edits that lead to length increase

Paste regularity

more sporadic more regular
Adapting Search to the Author
Towards Predicting Search Result Usefulness

**Objective:** Search engine should adapt to the author’s strategy.

Can we predict which documents will be useful?

Can we predict authors’ degree of retrieval success?
Essay Writing Visualization

- 1 hour and 100% final essay length
- 2 hours and 200% final essay length

- Query, result browsing
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Query, result browsing
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Linear Regression Model
90% Variance Explained
Contribution 2:
Enhancing Result Rankings with Axioms
Enhancing Result Rankings with Axioms

How to Tie a Tie | Tie-a-Tie.net
https://www.tie-a-tie.net/fourinhand/
Looking for an easy and versatile knot? Then the “Four in Hand” is the one. It is one of the simplest tie knots, making it a perfect pick for men new to wearing ties.

How to Tie a Tie - Apps on Google Play
Download this app and don’t waste your time and money searching the internet and trying to find out how to tie a decent knot on your own. Here they are - tens ...

How to Tie a Half Windsor Knot | The Tie Bar
https://www.thetiebar.com/how-to-tie/half-windsor
Learn how to tie a Half Windsor Knot and quickly become a Half Windsor expert with our easy, step-by-step instructions.

How To Tie A Tie Knot - 17 Different Ways of Tying Necktie Knots
https://www.realmenrealstyle.com/how-to-tie-a-tie/
I’m showing you 18 ways to tie a necktie, so you will be able to tie all the best tie knots – starting with the quickest and easiest tie knot, the Simple or Oriental ...

How to Tie a Tie: The Complete Guide | The Art of Manliness
https://www.artofmanliness.com/articles/how-to-tie-a-tie/
May 10, 2019 - It’s a sad fact, but there are grown men who don’t know how to tie a tie. If they have a big interview that afternoon, they’ll go shopping for a ...

How To Tie A Windsor Knot | Ties.com
https://www.ties.com/how-to-tie-a-tie/windsor
Although the Duke of Windsor never specifically used the Windsor knot, he did favor a wide triangular knot. In actuality, the Duke achieved his trendsetting look by tying a Four-in-Hand with specially made wide and extra thick ties. The Windsor knot was invented by the public as a ...

How To Tie A Simple Knot - Half Windsor - “Double Windsor” knot
Enhancing Result Rankings with Axioms

Four in hand | Tie-a-Tie.net
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Popular Ways to Tie A Necktie | Bows-N-Ties.com
https://www.bows-n-ties.com/how-to-tie-a-necktie/ ⬇️
The tie knots listed below are sorted by difficulty, starting with the popular and easy to master Four-in-Hand knot, and ending with the more challenging dimpled ...

Tie-a-Tie.net
https://www.tie-a-tie.net/ ⬇️
Learn how to tie a tie with the Windsor, Half Windsor, Four in Hand and Pratt necktie knots by following step-by-step video instructions and colored diagrams ...

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Enhancing Result Rankings with Axioms

Retrieval Models


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<td>08</td>
<td>76</td>
<td>86</td>
<td>14</td>
<td>03</td>
</tr>
</tbody>
</table>

Empirical Models

- Boolean
- VSM
- FuzzySet
- GVSM
- LSI
- Genre
- SuffixTree
- DivRand
- WebGenre
- CL-ESA
- ESA

Probabilistic Models

- ProbabilityIndex
- 2-Poisson
- BIM
- BII
- Inquery
- BeliefNet
- BestMatch
- LanguageModel
- LDA
- Doc2Vec
- MixtureUnigram
- pLSI

Language Models

- Language Model
- LDA
Strong retrieval models share similar heuristics
# Enhancing Result Rankings with Axioms

## Retrieval Axioms

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Axioms</th>
<th>Source</th>
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</thead>
<tbody>
<tr>
<td>Term frequency</td>
<td>TFC1–TFC3</td>
<td>[Fang, Tao, Zhai; SIGIR'04]</td>
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<tr>
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<td>TDC</td>
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<td>QLNC</td>
<td>[Cummins, O'Riordan; CIKM'12]</td>
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<tr>
<td>Lower bound</td>
<td>LB1 + LB2</td>
<td>[Lv, Zhai; CIKM’11]</td>
</tr>
<tr>
<td>Query aspects</td>
<td>REG</td>
<td>[Zheng, Fang; ECIR’10]</td>
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<td></td>
<td>DIV</td>
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Only used in theoretical analysis of retrieval models so far.
Axiomatic Result Re-ranking

Research Questions

Can fixing axiom violations improve individual rankings?

How to incorporate axioms directly into the retrieval process?
Axiomatic Result Re-ranking

Axiomatic Re-ranking Pipeline

1. Retrieve an initial top-$k$ result set.
2. (a) Compute re-ranking preferences of various axioms.
   (b) Aggregate re-ranking preferences.
3. Re-rank the initial result set.

Meta learning of axiom impact

KwikSort algorithm
1. Retrieve an initial top-$k$ result set.
1. Retrieve an initial top-\(k\) result set.

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Axiomatic Result Re-ranking

**Detail Step 2a**

1. Retrieve an initial top-$k$ result set.

2. (a) **Compute re-ranking preferences of various axioms.**
   (b) Aggregate re-ranking preferences.

3. Re-rank the initial result set.
Axiomatic Result Re-ranking

Detail Step 2a

Re-state existing axioms as binary predicates:

\[ A(q, d_1, d_2) = \begin{cases} 1 & \text{if } d_1 >_A d_2 \text{ given } q \\ 0 & \text{otherwise.} \end{cases} \]

\[ q \] query
\[ d_1, d_2 \] documents
\[ d_1 >_A d_2 \] \(d_1\) should be ranked higher according to axiom \(A\)
## Axiomatic Result Re-ranking

Adapting Existing Axioms to Express Re-Ranking Preferences

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Acronyms</th>
<th>Adapted</th>
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</thead>
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<tr>
<td>Term frequency</td>
<td>TFC1–TFC3, TDC</td>
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Axiomatic Result Re-ranking

Detail Step 2b

Given a top-$k$ ranking, each axiom produces a $k$-by-$k$ preference matrix.

Goal: Aggregate the individual preference matrices for a set of axioms.
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**Goal:** Aggregate the individual preference matrices for a set of axioms.

**Hypothesis:** Rankings from different retrieval models deviate from the axiomatic constraints in different ways.
Given a top-$k$ ranking, each axiom produces a $k$-by-$k$ preference matrix.

**Goal:** Aggregate the individual preference matrices for a set of axioms.

**Hypothesis:** Rankings from different retrieval models deviate from the axiomatic constraints in different ways.

**Approach:** Learn a preference aggregation function specific to the retrieval model.
Axiomatic Result Re-ranking

Detail Step 3

Aggregated preference matrix may still contain contradictions.

Resolve via minimum feedback arc set approximation.
Experimental Evaluation

Fixing axiom violations in individual rankings does help.

16 different retrieval models over ClueWeb09
120 training queries + 60 test queries

Average nDCG@10 over test queries

- Hiemstra_LM
- DirichletLM
- DLH
- PL2
- DLH13
- LemurTF_IDF
- DFR_BM25
- BB2
- InL2
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Experimental Evaluation

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16 different retrieval models over ClueWeb09
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Summary

Authors using a search engine. . .

- Tend follow one of two opposite strategies
- Can be supported by search engines that predict retrieval success

Search engine result rankings. . .

- Can be made to conform to theoretically sound retrieval axioms
- Especially if the basis retrieval model is weak
Colleagues, Collaborators, Students, Friends & Family...

Thank you!