

*Series Editor*

W. Bruce Croft

*Editorial Board*

ChengXiang Zhai

Maarten de Rijke

Nicholas J. Belkin

Charles Clarke

Donald Metzler

# A Feature-Centric View of Information Retrieval

 Springer

Donald Metzler  
Natural Language Group  
Information Sciences Institute  
University of Southern California  
4676 Admiralty Way, Suite 1001  
Marina del Rey, CA 90292  
USA  
[metzler@isi.edu](mailto:metzler@isi.edu)

ISSN 1387-5264 The Information Retrieval Series  
ISBN 978-3-642-22897-1 e-ISBN 978-3-642-22898-8  
DOI 10.1007/978-3-642-22898-8  
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2011937284

ACM Computing Classification (1998): H.3.3, G.3

© Springer-Verlag Berlin Heidelberg 2011

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

*Cover design:* VTeX UAB, Lithuania

Printed on acid-free paper

Springer is part of Springer Science+Business Media ([www.springer.com](http://www.springer.com))

*To* 晓黎

# Acknowledgements

The material presented in this book represents the culmination of a line of research that began while I was a graduate student at the University of Massachusetts, Amherst. A great deal of the work presented here would not have been possible without a great cast of collaborators. First, and foremost, I must thank W. Bruce Croft for all of his support during my Ph.D. studies. I am also very grateful to Michael Bendersky, Jimmy Lin, Lidan Wang, and Hao Lang, all of whom made significant contributions that have greatly advanced and pushed this particular line of research well beyond where it was just a few years ago.

# Contents

|          |   |    |
|----------|---|----|
| <b>1</b> | <b>Introduction</b>                                     | 1  |
| 1        | From Archie to Google and Beyond                        | 1  |
| 2        | The Academic and Industrial Perspectives                | 1  |
| 3        | Paradigm Shifts   | 2  |
| 4        | A Robust Retrieval Model                                | 5  |
| 5        | Outline   | 6  |
| <b>2</b> | <b>Classical Retrieval Models</b>                       | 7  |
| 1        | Overview  | 7  |
| 2        | Bag of Words Models                                     | 7  |
| 2.1      | Binary Independence Retrieval Model                     | 8  |
| 2.2      | 2-Poisson Model   | 12 |
| 2.3      | BM25 Model  | 13 |
| 2.4      | Unigram Language Models                                 | 14 |
| 2.5      | Other Bag of Words Models                               | 15 |
| 3        | Models That Go Beyond the Bag of Words Assumption       | 16 |
| 3.1      | $n$ -Gram Language Models                               | 16 |
| 3.2      | Indri Inference Network Model                           | 17 |
| 3.3      | Other Models That Go Beyond the Bag of Words Assumption | 21 |
| 4        | The Current State-of-the-Art                            | 22 |
| <b>3</b> | <b>Feature-Based Ranking</b>                            | 23 |
| 1        | Overview  | 23 |
| 2        | Modeling Relevance                                      | 23 |
| 3        | The Markov Random Field Model                           | 24 |
| 3.1      | Graph Structure   | 26 |
| 3.2      | Potential Functions                                     | 27 |
| 4        | Constructing Markov Random Fields                       | 29 |
| 4.1      | Dependence Model Type                                   | 30 |
| 4.2      | Clique Set Type   | 30 |

|          |  |            |
|----------|--|------------|
| 4.3      | Weighting Function . . . . .                       | 32         |
| 4.4      | Examples . . . . .                                 | 35         |
| 5        | Ranking . . . . .                                  | 37         |
| 6        | Ad Hoc Retrieval . . . . .                         | 39         |
| 6.1      | MRF Models for Ad Hoc Retrieval . . . . .          | 41         |
| 6.2      | Evaluation . . . . .                               | 49         |
| 6.3      | Summary of Results . . . . .                       | 66         |
| 7        | Web Search . . . . .                               | 67         |
| 7.1      | Previous Models for Web Search . . . . .           | 69         |
| 7.2      | Document Priors . . . . .                          | 70         |
| 7.3      | MRF Models for Web Search . . . . .                | 73         |
| 7.4      | Results . . . . .                                  | 75         |
| <b>4</b> | <b>Feature-Based Query Expansion . . . . .</b>     | <b>79</b>  |
| 1        | Overview . . . . .                                 | 79         |
| 2        | Related Work . . . . .                             | 80         |
| 3        | Basic Latent Concept Expansion . . . . .           | 81         |
| 3.1      | Query Expansion . . . . .                          | 84         |
| 3.2      | Comparison to Relevance Models . . . . .           | 84         |
| 4        | Generalized Latent Concept Expansion . . . . .     | 85         |
| 4.1      | Features . . . . .                                 | 86         |
| 4.2      | Comparison with Previous Models . . . . .          | 86         |
| 5        | LCE Using Hierarchical MRFs . . . . .              | 88         |
| 5.1      | Data Representation . . . . .                      | 88         |
| 5.2      | Model Description . . . . .                        | 89         |
| 5.3      | Discussion . . . . .                               | 91         |
| 5.4      | Time Complexity . . . . .                          | 92         |
| 5.5      | HMRFs for Ranking . . . . .                        | 93         |
| 6        | Experimental Results . . . . .                     | 94         |
| 6.1      | Ad Hoc Retrieval Results . . . . .                 | 94         |
| 6.2      | Robustness . . . . .                               | 97         |
| 6.3      | Multi-term Concept Generation . . . . .            | 98         |
| 6.4      | Evaluation of LCE-GE and LCE-HMRF . . . . .        | 100        |
| 7        | Discussion . . . . .                               | 105        |
| 7.1      | Relevance vs. Relevant Documents . . . . .         | 105        |
| 7.2      | The Role of Dependence . . . . .                   | 105        |
| <b>5</b> | <b>Query-Dependent Feature Weighting . . . . .</b> | <b>107</b> |
| 1        | Overview . . . . .                                 | 107        |
| 2        | Related Work . . . . .                             | 108        |
| 3        | Weighted Dependence Model . . . . .                | 109        |
| 4        | Concept Importance Features . . . . .              | 111        |
| 5        | Evaluation . . . . .                               | 113        |
| 5.1      | Experimental Setup . . . . .                       | 113        |
| 5.2      | TREC Evaluation . . . . .                          | 114        |
| 5.3      | Large-Scale Web Evaluation . . . . .               | 117        |

- 6 Model Learning . . . . . 121**
  - 1 Parameter Estimation . . . . . 121
    - 1.1 Direct Search . . . . . 122
    - 1.2 Optimization Using Surrogate Functions . . . . . 125
  - 2 Feature Selection . . . . . 128
    - 2.1 Related Work . . . . . 129
    - 2.2 Automatic Feature Selection . . . . . 129
    - 2.3 Evaluation . . . . . 131
  - 3 Learning to Efficiently Rank . . . . . 136
    - 3.1 Related Work . . . . . 137
    - 3.2 Tradeoff Metrics . . . . . 138
    - 3.3 Model . . . . . 141
    - 3.4 Parameter Estimation . . . . . 143
    - 3.5 Experimental Results . . . . . 143
- Appendix A Data Sets . . . . . 149**
  - 1 Anatomy of a TREC Data Set . . . . . 149
  - 2 Summary of Data Sets . . . . . 151
- Appendix B Evaluation Metrics . . . . . 153**
- References . . . . . 157**
- Index . . . . . 165**