DATA MINING AND ANALYSIS

Fundamental Concepts and Algorithms

MOHAMMED J. ZAKI
Rensselaer Polytechnic Institute, Troy, New York

WAGNER MEIRA JR.
Universidade Federal de Minas Gerais, Brazil

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

32 Avenue of the Americas, New York, NY 10013-2473, USA

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9780521766333

First published 2014

A catalog record for this publication is available from the British Library.

Library of Congress Cataloging in Publication Data
Zaki, Mohammed J., 1971–
Data mining and analysis: fundamental concepts and algorithms / Mohammed J. Zaki, Rensselaer Polytechnic Institute, Troy, New York, Wagner Meira Jr., Universidade Federal de Minas Gerais, Brazil.
pages cm
Includes bibliographical references and index.
ISBN 978-0-521-76633-3 (hardback)
1. Data mining. I. Meira, Wagner, 1967– II. Title.
QA76.9.D343Z36 2014
006.3′12–dc23 2013037544

ISBN 978-0-521-76633-3 Hardback

Contents

Preface

This book is an outgrowth of data mining courses at Rensselaer Polytechnic Institute (RPI) and Universidade Federal de Minas Gerais (UFMG); the RPI course has been offered every Fall since 1998, whereas the UFMG course has been offered since 2002. Although there are several good books on data mining and related topics, we felt that many of them are either too high-level or too advanced. Our goal was to write an introductory text that focuses on the fundamental algorithms in data mining and analysis. It lays the mathematical foundations for the core data mining methods, with key concepts explained when first encountered; the book also tries to build the intuition behind the formulas to aid understanding.

The main parts of the book include exploratory data analysis, frequent pattern mining, clustering, and classification. The book lays the basic foundations of these tasks, and it also covers cutting-edge topics such as kernel methods, high-dimensional data analysis, and complex graphs and networks. It integrates concepts from related disciplines such as machine learning and statistics and is also ideal for a course on data analysis. Most of the prerequisite material is covered in the text, especially on linear algebra, and probability and statistics.

The book includes many examples to illustrate the main technical concepts. It also has end-of-chapter exercises, which have been used in class. All of the algorithms in the book have been implemented by the authors. We suggest that readers use their favorite data analysis and mining software to work through our examples and to implement the algorithms we describe in text; we recommend the R software or the Python language with its NumPy package. The datasets used and other supplementary material such as project ideas and slides are available online at the book's companion site and its mirrors at RPI and UFMG:

- `http://dataminingbook.info`
- `http://www.cs.rpi.edu/~zaki/dataminingbook`
- `http://www.dcc.ufmg.br/dataminingbook`

Having understood the basic principles and algorithms in data mining and data analysis, readers will be well equipped to develop their own methods or use more advanced techniques.

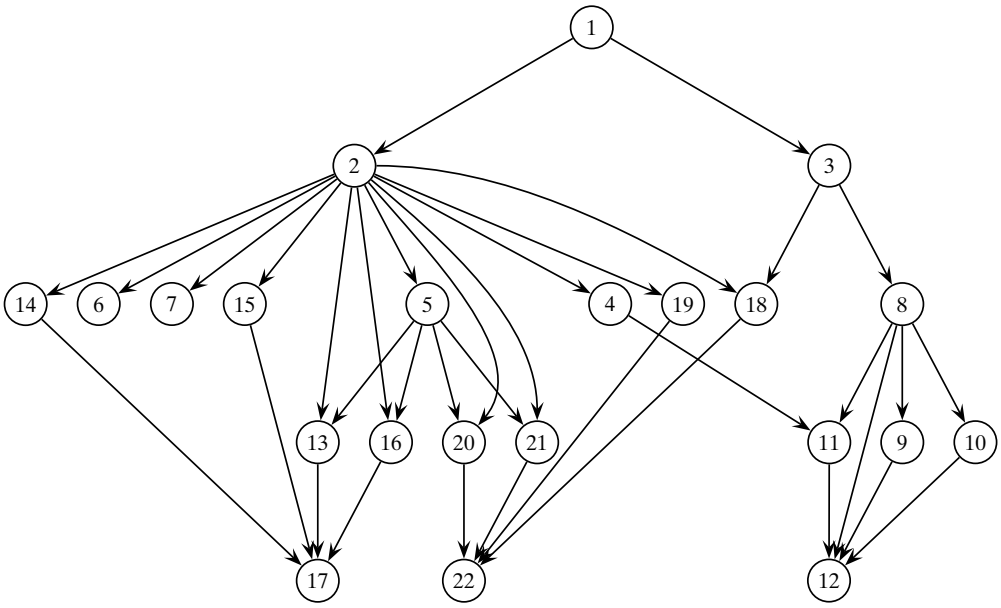

Figure 0.1. Chapter dependencies

Suggested Roadmaps

The chapter dependency graph is shown in Figure 0.1. We suggest some typical roadmaps for courses and readings based on this book. For an undergraduate-level course, we suggest the following chapters: 1–3, 8, 10, 12–15, 17–19, and 21–22. For an undergraduate course without exploratory data analysis, we recommend Chapters 1, 8–15, 17–19, and 21–22. For a graduate course, one possibility is to quickly go over the material in Part I or to assume it as background reading and to directly cover Chapters 9–22; the other parts of the book, namely frequent pattern mining (Part II), clustering (Part III), and classification (Part IV), can be covered in any order. For a course on data analysis the chapters covered must include 1–7, 13–14, 15 (Section 2), and 20. Finally, for a course with an emphasis on graphs and kernels we suggest Chapters 4, 5, 7 (Sections 1–3), 11–12, 13 (Sections 1–2), 16–17, and 20–22.

Acknowledgments

Initial drafts of this book have been used in several data mining courses. We received many valuable comments and corrections from both the faculty and students. Our thanks go to

- Muhammad Abulaish, Jamia Millia Islamia, India
- Mohammad Al Hasan, Indiana University Purdue University at Indianapolis
- Marcio Luiz Bunte de Carvalho, Universidade Federal de Minas Gerais, Brazil
- Loïc Cerf, Universidade Federal de Minas Gerais, Brazil
- Ayhan Demiriz, Sakarya University, Turkey
- Murat Dundar, Indiana University Purdue University at Indianapolis
- Jun Luke Huan, University of Kansas
- Ruoming Jin, Kent State University
- Latifur Khan, University of Texas, Dallas

- Pauli Miettinen, Max-Planck-Institut für Informatik, Germany
- Suat Ozdemir, Gazi University, Turkey
- Naren Ramakrishnan, Virginia Polytechnic and State University
- Leonardo Chaves Dutra da Rocha, Universidade Federal de São João del-Rei, Brazil
- Saeed Salem, North Dakota State University
- Ankur Teredesai, University of Washington, Tacoma
- Hannu Toivonen, University of Helsinki, Finland
- Adriano Alonso Veloso, Universidade Federal de Minas Gerais, Brazil
- Jason T.L. Wang, New Jersey Institute of Technology
- Jianyong Wang, Tsinghua University, China
- Jiong Yang, Case Western Reserve University
- Jieping Ye, Arizona State University

We would like to thank all the students enrolled in our data mining courses at RPI and UFMG, as well as the anonymous reviewers who provided technical comments on various chapters. We appreciate the collegial and supportive environment within the computer science departments at RPI and UFMG and at the Qatar Computing Research Institute. In addition, we thank NSF, CNPq, CAPES, FAPEMIG, Inweb – the National Institute of Science and Technology for the Web, and Brazil's Science without Borders program for their support. We thank Lauren Cowles, our editor at Cambridge University Press, for her guidance and patience in realizing this book.

Finally, on a more personal front, MJZ dedicates the book to his wife, Amina, for her love, patience and support over all these years, and to his children, Abrar and Afsah, and his parents. WMJ gratefully dedicates the book to his wife Patricia; to his children, Gabriel and Marina; and to his parents, Wagner and Marlene, for their love, encouragement, and inspiration.