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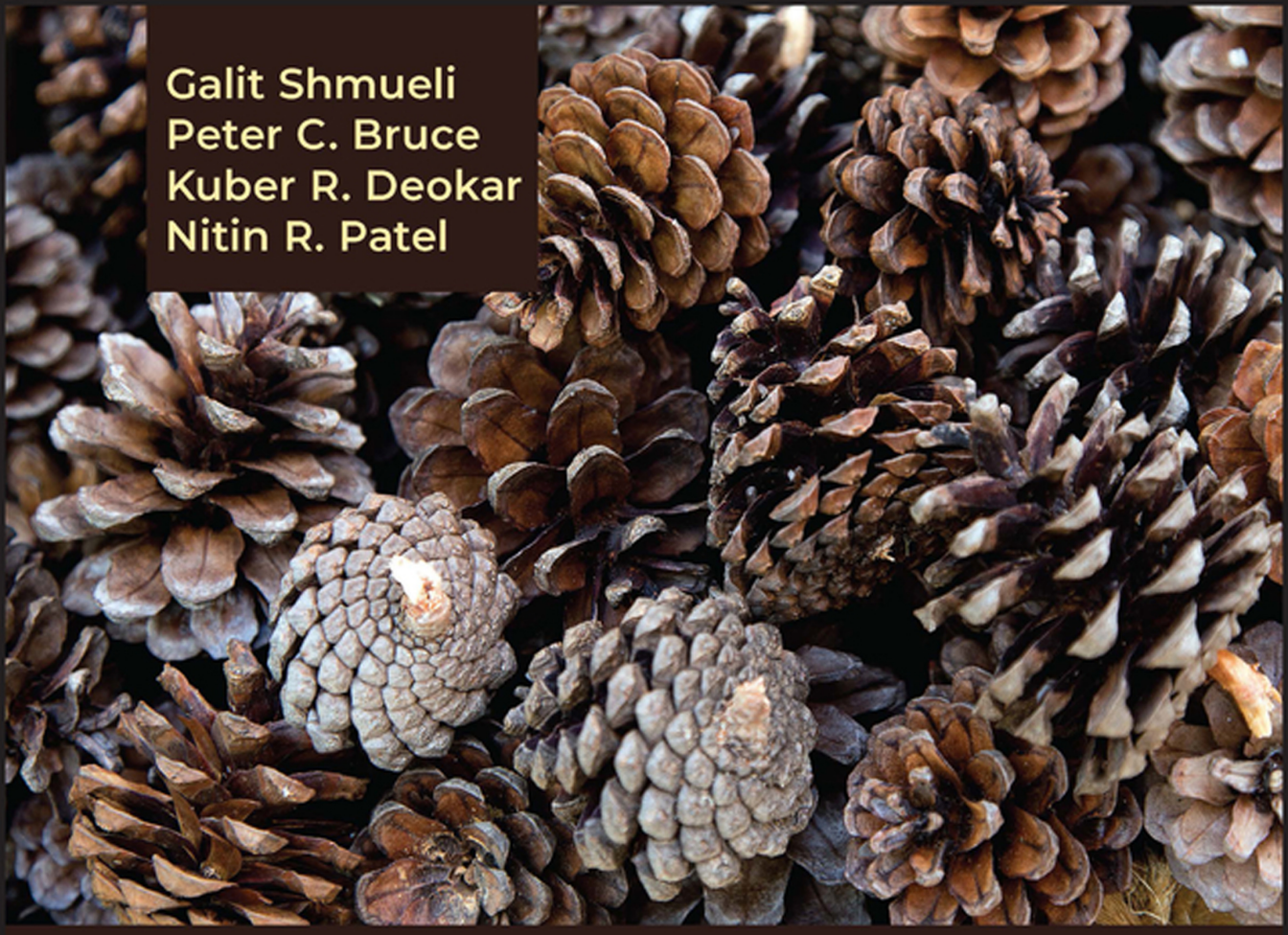

FOURTH EDITION

MACHINE LEARNING FOR BUSINESS ANALYTICS

Concepts, Techniques, and Applications with Analytic Solver® Data Mining

WILEY

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Concepts, Techniques, and Applications with Analytic Solver® Data Mining

Fourth Edition

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To our families

Boaz and Noa

Liz, Lisa, and Allison

Komal and Yash

Tehmi, Arjun, and in

memory of Aneesh

Contents

Foreword

I was tasked to develop a course on statistical and machine learning for our new business analytics program at a major public university almost a decade ago. I quickly discovered that, unlike business statistics and management science, a legacy of textbooks on this subject appropriate for students without an extensive mathematical background did not exist. Fortunately, a colleague at another institution pointed me toward *Data Mining for Business Intelligence*, the 2nd edition of this book (now called *Machine Learning for Business Analytics*), and it has been the core text for my predictive analytics course ever since. My initial choice was validated, and the book is still the best choice for our students.

Universities are now offering a wide range of degrees, concentrations, and certificates in business analytics. Success with analytics is grounded in employees with the requisite skills to meet industry needs. The market for business analytics continues to expand rapidly as companies adopt new technologies to manage and understand business processes using enterprise, e-commerce, and sensor data. Numerous media and vendor reports have documented the contribution of predictive analytics to improved business outcomes. More recently, analytical solutions have been extended to incorporate artificial intelligence using advanced maching learning techniques, thereby reducing labor costs, enhancing customer experiences, and improving cybersecurity. Negotiating such a new constellation of developing frontiers requires good integrated learning resources. This book is certainly one of them.

The genesis of this book, now in its 4th edition with a revised title, was to make machine learning accessible to students outside of traditional STEM disciplines. It uses the Analytic Solver® add-in for Excel from Frontline Systems, Inc., to quickly introduce students to the machine learning process in a spreadsheet environment without the need for writing computer code. With the Data Mining module of Analytic Solver, students can gain hands-on skills with a broad range of data visualization, data handling utilities, and statistical and machine learning techniques, augmented by tools for data partitioning, variable transformation, feature selection, and model performance evaluation. As a result, both instructors and students are free to focus on conceptual learning using data

sets that illustrate a variety of use cases for machine learning in the major functional areas of business.

While this book is also available in other editions based on alternative software platforms, I can speak firsthand as to how its content when used in conjunction with Analytic Solver facilitates a concrete understanding of how statistical and machine learning algorithms work. Students can interactively experiment with the effects of changing algorithmic settings and explore the detailed reports and charts generated by Analytic Solver to review intermediate calculations. By the end of each chapter, students can describe the primary mechanism being used by an algorithm for classification or prediction, articulate its requirements in terms of input variables and parameters, interpret its results, and identify its strengths and weaknesses. They are also exposed to carefully crafted business scenarios and associated real data for each topic. With this foundation, they will be well-prepared for a data analyst role in their respective domains, as well as further study of advanced analytics.

The authors of this book bring together a combination of extensive academic and industry experience that makes a unique contribution to the textbook landscape. In this new edition, they have updated the text and figures to correspond to the latest version of Analytic Solver, expanded coverage of metrics for assessing model performance, and added contemporary topics including deep learning and ethical considerations in the use of data science.

If you are a newcomer to teaching in this area of predictive analytics, *Machine Learning for Business Analytics* will support you and your students while you gain traction in the classroom. With more background, it will serve as a useful resource to guide your own discovery and acquisition of new knowledge and skills for machine learning.

SUSAN W. PALOCSAY
James Madison University 2023

Preface to the Fourth Edition

This textbook first appeared in early 2007 and has been used by numerous students and practitioners and in many courses, including our own experience teaching this material both online and in person for more than 15 years. The first edition, based on the Excel add-in Analytic Solver Data Mining (ASDM, previously XLMiner), was followed by two more Analytic Solver editions, a JMP edition, two R editions, a Python edition, a RapidMiner edition, and now this 4th edition with Analytic Solver, with its companion website, www.dataminingbook.com.

As in the previous Analytic Solver editions, the focus in this new edition is on machine learning concepts and how to implement the associated algorithms in Analytic Solver Data Mining.

For this new ASDM edition, a new co-author, Kuber Deokar, comes on board bringing extensive experience in online course design, development, and delivery, including using ASDM. He has taught courses using various editions of this book for over a decade and has helped shape the student experience in many ways.

The new edition provides significant updates both in terms of ASDM and in terms of new topics and content. In addition to updating software routines and outputs that have changed or become available since the 3rd edition, this edition also incorporates updates and new material based on feedback from instructors teaching MBA, MS, undergraduate, diploma, and executive courses, and from their students as well. Importantly, this edition includes several new topics:

- A new chapter on *Responsible Data Science* (Chapter 22) covering topics of fairness, transparency, model cards and datasheets, legal considerations, and more, with an illustrative example.
- A dedicated section on *deep learning* in Chapter 11.
- The *Performance Evaluation* exposition in Chapter 5 was expanded to include further metrics (precision and recall, F1).
- A new chapter on *Generating, Comparing, and Combining Multiple Models* (Chapter 13) that covers ensembles and AutoML.

- A new chapter dedicated to *Interventions and User Feedback* (Chapter 14) that covers A/B tests, uplift modeling, and reinforcement learning.
- A new case (Loan Approval) that touches on regulatory and ethical issues.

A note about the book's title: The first two editions of the book used the title *Data Mining for Business Intelligence*. Business Intelligence today refers mainly to reporting and data visualization ("what is happening now"), while Business Analytics has taken over the "advanced analytics," which include predictive analytics and data mining. Later editions were therefore renamed *Data Mining for Business Analytics*. However, the recent AI transformation has made the term *machine learning* more popularly associated with the methods in this textbook. In this new edition, we therefore use the updated terms *Machine Learning* and *Business Analytics*.

Since the appearance of the (Analytic Solver based) second edition, the landscape of the courses using the textbook has greatly expanded: whereas initially, the book was used mainly in semester-long elective MBA-level courses, it is now used in a variety of courses in Business Analytics degrees and certificate programs, ranging from undergraduate programs, to post-graduate and executive education programs. Courses in such programs also vary in their duration and coverage. In many cases, this textbook is used across multiple courses. The book is designed to continue supporting the general "Predictive Analytics" or "Data Mining" course as well as supporting a set of courses in dedicated business analytics programs.

A general "Business Analytics," "Predictive Analytics," or "Machine Learning" course, common in MBA and undergraduate programs as a one-semester elective, would cover Parts I–III, and choose a subset of methods from Parts IV and V. Instructors can choose to use cases as team assignments, class discussions, or projects. For a two-semester course, Part VII might be considered, and we recommend introducing Part VIII (Data Analytics).

For a set of courses in a dedicated business analytics program, here are a few courses that have been using our book:

Predictive Analytics—Supervised Learning: In a dedicated Business Analytics program, the topic of Predictive Analytics is typically instructed across a set of courses. The first course would cover Parts I–III and instructors typically choose a subset of methods from Part IV according to the course length. We recommend including "Part VIII: Data Analytics."

Predictive Analytics—Unsupervised Learning: This course introduces data exploration and visualization, dimension reduction, mining relationships, and clustering (Parts II and VI). If this course follows the Predictive Analytics: Supervised Learning course, then it is useful to examine examples and approaches that integrate unsupervised and supervised learning, such as Part VIII on Data Analytics.

Forecasting Analytics: A dedicated course on time series forecasting would rely on Part VI.

Advanced Analytics: A course that integrates the learnings from Predictive Analytics (supervised and unsupervised learning) can focus on Part VIII: Data Analytics, where social network analytics and text mining are introduced, and responsible data science is discussed. Such a course might also include Chapter 13, Generating, Comparing, and Combining Multiple Models and AutoML from Part IV, as well as Part V, which covers experiments, uplift, and reinforcement learning. Some instructors choose to use the Cases (Chapter 23) in such a course.

In all courses, we strongly recommend including a project component, where data are either collected by students according to their interest or provided by the instructor (e.g., from the many machine learning competition datasets available). From our experience and other instructors' experience, such projects enhance the learning and provide students with an excellent opportunity to understand the strengths of machine learning and the challenges that arise in the process.

GALIT SHMUELI, PETER C. BRUCE, KUBER R. DEOKAR, AND NITIN R. PATEL
2023

Acknowledgments

We thank the many people who assisted us in improving the book from its inception as *Data Mining for Business Intelligence* in 2006 (using XLMiner, now Analytic Solver), its reincarnation as *Data Mining for Business Analytics*, and now *Machine Learning for Business Analytics*, including translations in Chinese and Korean and versions supporting Analytic Solver Data Mining, R, Python, SAS JMP, and RapidMiner.

Anthony Babinec, who has been using earlier editions of this book for years in his data mining courses at Statistics.com, provided us with detailed and expert corrections. Dan Toy and John Elder IV greeted our project with early enthusiasm and provided detailed and useful comments on initial drafts. Ravi Bapna, who used an early draft in a data mining course at the Indian School of Business and later at University of Minnesota, has provided invaluable comments and helpful suggestions since the book's start.

Many of the instructors, teaching assistants, and students using earlier editions of the book have contributed invaluable feedback both directly and indirectly, through fruitful discussions, learning journeys, and interesting data mining projects that have helped shape and improve the book. These include MBA students from the University of Maryland, MIT, the Indian School of Business, National Tsing Hua University, and Statistics.com. Instructors from many universities and teaching programs, too numerous to list, have supported and helped improve the book since its inception.

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