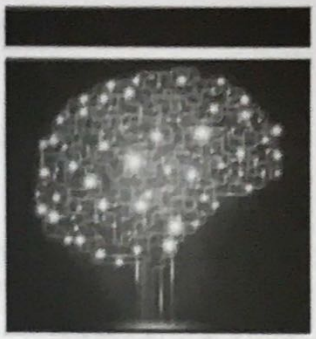
Machine Learning

HANDS-ON FOR DEVELOPERS AND TECHNICAL PROFESSIONALS

WILEY



Machine Learning

Hands-On for Developers and Technical Professionals

Jason Bell

WILEY

Machine Learning: Hands-On for Developers and Technical Professionals

Published by
John Wiley & Sons, Inc.
10475 Crosspoint Boulevard
Indianapolis, IN 46256
www.wiley.com

Published simultaneously in Canada

ISBN: 978-1-118-88906-0
ISBN: 978-1-118-88939-8 (ebk)
ISBN: 978-1-118-88949-7 (ebk)

Manufactured in the United States of America

10 9 8 7 6 5 4 3 2

Library of Congress Control Number: 2014946682

To Wendy and Clarissa.

Credits

Executive Editor
Carol Long

Project Editor
Charlotte Kughen

Technical Editor
Mitchell Wyle

Production Editor
Christine Mugnolo

Copy Editor
Katherine Burt

Production Manager
Kathleen Wisor

Manager of Content Development and Assembly
Mary Beth Wakefield

Director of Community Marketing
David Mayhew

Marketing Manager
Carrie Sherrill

Business Manager
Amy Knies

Professional Technology & Strategy Director
Barry Pruett

Associate Publisher
Jim Minatel

Project Coordinator, Cover
Patrick Redmond

Proofreader
Nancy Carrasco

Indexer
Johnna Dinse

Cover Designer
Wiley

Cover Image
© iStock.com/VLADGRIN

About the Author

Jason Bell has been working with point-of-sale and customer-loyalty data since 2002, and he has been involved in software development for more than 25 years. He is founder of Datasentiment, a UK business that helps companies worldwide with data acquisition, processing, and insight.

Acknowledgments

During the autumn of 2013, I was presented with some interesting options: either do a research-based PhD or co-author a book on machine learning. One would take six years and the other would take seven to eight months. Because of the speed the data industry was, and still is, progressing, the idea of the book was more appealing because I would be able to get something out while it was still fresh and relevant, and that was more important to me.

I say "co-author" because the original plan was to write a machine learning book with Aidan Rogers. Due to circumstances beyond his control he had to pull out. With Aidan's blessing, I continued under my own steam, and for that opportunity I can't thank him enough for his grace, encouragement, and support in that decision.

Many thanks goes to Wiley, especially Executive Editor, Carol Long, for letting me tweak things here and there with the original concept and bring it to a more practical level than a theoretical one; Project Editor, Charlotte Kughen, who kept me on the straight and narrow when there were times I didn't make sense; and Mitchell Wyle for reviewing the technical side of things. Also big thanks to the Wiley family as a whole for looking after me with this project.

Over the years I've met and worked with some incredible people, so in no particular order here goes: Garrett Murphy, Clare Conway, Colin Mitchell, David Crozier, Edd Dumbill, Matt Biddulph, Jim Weber, Tara Simpson, Marty Neill, John Girvin, Greg O'Hanlon, Clare Rowland, Tim Spear, Ronan Cunningham, Tom Grey, Stevie Morrow, Steve Orr, Kevin Parker, John Reid, James Blundell, Mary McKenna, Mark Nagurski, Alan Hook, Jon Brookes, Conal Loughrey, Paul Graham, Frankie Colclough, and countless others (whom I will be kicking myself that I've forgotten) for all the meetings, the chats, the ideas, and the collaborations.

Thanks to Tim Brundle, Matt Johnson, and Alan Thorburn for their support and for introducing me to the people who would inspire thoughts that would spur me on to bigger challenges with data. An enormous thank you to Thomas Spinks for having faith in me, without him there wouldn't have been a career in computing.

In relation to the challenge of writing a book I have to thank Ben Hammersley, Alistair Croll, Alasdair Allan, and John Foreman for their advice and support throughout the whole process.

I also must thank my dear friend, Colin McHale, who, on one late evening while waiting for the soccer data to refresh, taught me Perl on the back of a KitKat wrapper, thus kick-starting a journey of software development.

Finally, to my wife, Wendy, and my daughter, Clarissa, for absolutely everything and encouraging me to do this book to the best of my nerdy ability. I couldn't have done it without you both. And to the Bell family—George, Maggie and my sister Fern—who have encouraged my computing journey from a very early age.

During the course of writing this book, musical enlightenment was brought to me by St. Vincent, Trey Gunn, Suzanne Vega, Tackhead, Peter Gabriel, Doug Wimbish, King Crimson, and Level 42.

Contents

Introduction		**xix**
Chapter 1	**What Is Machine Learning?**	**1**
	History of Machine Learning	1
	Alan Turing	1
	Arthur Samuel	2
	Tom M. Mitchell	2
	Summary Definition	2
	Algorithm Types for Machine Learning	3
	Supervised Learning	3
	Unsupervised Learning	3
	The Human Touch	4
	Uses for Machine Learning	4
	Software	4
	Stock Trading	5
	Robotics	6
	Medicine and Healthcare	6
	Advertising	6
	Retail and E-Commerce	7
	Gaming Analytics	8
	The Internet of Things	9
	Languages for Machine Learning	10
	Python	10
	R	10
	Matlab	10
	Scala	10
	Clojure	11
	Ruby	11

Software Used in This Book 11
Checking the Java Version 11
Weka Toolkit 12
Mahout 12
SpringXD 13
Hadoop 13
Using an IDE 14
Data Repositories 14
UC Irvine Machine Learning Repository 14
Infochimps 14
Kaggle 15
Summary 15

Chapter 2 Planning for Machine Learning 17
The Machine Learning Cycle 17
It All Starts with a Question 18
I Don't Have Data! 19
Starting Local 19
Competitions 19
One Solution Fits All? 20
Defining the Process 20
Planning 20
Developing 21
Testing 21
Reporting 21
Refining 22
Production 22
Building a Data Team 22
Mathematics and Statistics 22
Programming 23
Graphic Design 23
Domain Knowledge 23
Data Processing 23
Using Your Computer 24
A Cluster of Machines 24
Cloud-Based Services 24
Data Storage 25
Physical Discs 25
Cloud-Based Storage 25
Data Privacy 25
Cultural Norms 25
Generational Expectations 26
The Anonymity of User Data 26
Don't Cross "The Creepy Line" 27
Data Quality and Cleaning 28
Presence Checks 28

Type Checks 29
Length Checks 29
Range Checks 30
Format Checks 30
The Britney Dilemma 30
What's in a Country Name? 33
Dates and Times 35
Final Thoughts on Data Cleaning 35
Thinking about Input Data 36
Raw Text 36
Comma Separated Variables 36
JSON 37
YAML 39
XML 39
Spreadsheets 40
Databases 41
Thinking about Output Data 42
Don't Be Afraid to Experiment 42
Summary 43

Chapter 3 Working with Decision Trees 45
The Basics of Decision Trees 45
Uses for Decision Trees 45
Advantages of Decision Trees 46
Limitations of Decision Trees 46
Different Algorithm Types 47
How Decision Trees Work 48
Decision Trees in Weka 53
The Requirement 53
Training Data 53
Using Weka to Create a Decision Tree 55
Creating Java Code from the Classification 60
Testing the Classifier Code 64
Thinking about Future Iterations 66
Summary 67

Chapter 4 Bayesian Networks 69
Pilots to Paperclips 69
A Little Graph Theory 70
A Little Probability Theory 72
Coin Flips 72
Conditional Probability 72
Winning the Lottery 73
Bayes' Theorem 73
How Bayesian Networks Work 75
Assigning Probabilities 76
Calculating Results 77

	Node Counts	78
	Using Domain Experts	78
	A Bayesian Network Walkthrough	79
	Java APIs for Bayesian Networks	79
	Planning the Network	79
	Coding Up the Network	81
	Summary	90
Chapter 5	**Artificial Neural Networks**	**91**
	What Is a Neural Network?	91
	Artificial Neural Network Uses	92
	High-Frequency Trading	92
	Credit Applications	93
	Data Center Management	93
	Robotics	93
	Medical Monitoring	93
	Breaking Down the Artificial Neural Network	94
	Perceptrons	94
	Activation Functions	95
	Multilayer Perceptrons	96
	Back Propagation	98
	Data Preparation for Artificial Neural Networks	99
	Artificial Neural Networks with Weka	100
	Generating a Dataset	100
	Loading the Data into Weka	102
	Configuring the Multilayer Perceptron	103
	Training the Network	105
	Altering the Network	108
	Increasing the Test Data Size	108
	Implementing a Neural Network in Java	109
	Create the Project	109
	The Code	111
	Converting from CSV to Arff	114
	Running the Neural Network	114
	Summary	115
Chapter 6	**Association Rules Learning**	**117**
	Where Is Association Rules Learning Used?	117
	Web Usage Mining	118
	Beer and Diapers	118
	How Association Rules Learning Works	119
	Support	121
	Confidence	121
	Lift	122
	Conviction	122
	Defining the Process	122

Algorithms 123
Apriori 123
FP-Growth 124
Mining the Baskets—A Walkthrough 124
Downloading the Raw Data 124
Setting Up the Project in Eclipse 125
Setting Up the Items Data File 126
Setting Up the Data 129
Running Mahout 131
Inspecting the Results 133
Putting It All Together 135
Further Development 136
Summary 137

Chapter 7 Support Vector Machines 139
What Is a Support Vector Machine? 139
Where Are Support Vector Machines Used? 140
The Basic Classification Principles 140
Binary and Multiclass Classification 140
Linear Classifiers 142
Confidence 143
Maximizing and Minimizing to Find the Line 143
How Support Vector Machines Approach Classification 144
Using Linear Classification 144
Using Non-Linear Classification 146
Using Support Vector Machines in Weka 147
Installing LibSVM 147
A Classification Walkthrough 148
Implementing LibSVM with Java 154
Summary 159

Chapter 8 Clustering 161
What Is Clustering? 161
Where Is Clustering Used? 162
The Internet 162
Business and Retail 163
Law Enforcement 163
Computing 163
Clustering Models 164
How the K-Means Works 164
Calculating the Number of Clusters in a Dataset 166
K-Means Clustering with Weka 168
Preparing the Data 168
The Workbench Method 169
The Command-Line Method 174
The Coded Method 178
Summary 186

Chapter 9 Machine Learning in Real Time with Spring XD 187
Capturing the Firehose of Data 187
Considerations of Using Data in Real Time 188
Potential Uses for a Real-Time System 188
Using Spring XD 189
Spring XD Streams 190
Input Sources, Sinks, and Processors 190
Learning from Twitter Data 193
The Development Plan 193
Configuring the Twitter API Developer Application 194
Configuring Spring XD 196
Starting the Spring XD Server 197
Creating Sample Data 198
The Spring XD Shell 198
Streams 101 199
Spring XD and Twitter 202
Setting the Twitter Credentials 202
Creating Your First Twitter Stream 203
Where to Go from Here 205
Introducing Processors 206
How Processors Work within a Stream 206
Creating Your Own Processor 207
Real-Time Sentiment Analysis 215
How the Basic Analysis Works 215
Creating a Sentiment Processor 217
Spring XD Taps 221
Summary 222

Chapter 10 Machine Learning as a Batch Process 223
Is It Big Data? 223
Considerations for Batch Processing Data 224
Volume and Frequency 224
How Much Data? 225
Which Process Method? 225
Practical Examples of Batch Processes 225
Hadoop 225
Sqoop 226
Pig 226
Mahout 226
Cloud-Based Elastic Map Reduce 226
A Note about the Walkthroughs 227
Using the Hadoop Framework 227
The Hadoop Architecture 227
Setting Up a Single-Node Cluster 229

How MapReduce Works 233
Mining the Hashtags 234
Hadoop Support in Spring XD 235
Objectives for This Walkthrough 235
What's a Hashtag? 235
Creating the MapReduce Classes 236
Performing ETL on Existing Data 247
Product Recommendation with Mahout 250
Mining Sales Data 256
Welcome to My Coffee Shop! 257
Going Small Scale 258
Writing the Core Methods 258
Using Hadoop and MapReduce 260
Using Pig to Mine Sales Data 263
Scheduling Batch Jobs 273
Summary 274

Chapter 11 Apache Spark 275
Spark: A Hadoop Replacement? 275
Java, Scala, or Python? 276
Scala Crash Course 276
Installing Scala 276
Packages 277
Data Types 277
Classes 278
Calling Functions 278
Operators 279
Control Structures 279
Downloading and Installing Spark 280
A Quick Intro to Spark 280
Starting the Shell 281
Data Sources 282
Testing Spark 282
Spark Monitor 284
Comparing Hadoop MapReduce to Spark 285
Writing Standalone Programs with Spark 288
Spark Programs in Scala 288
Installing SBT 288
Spark Programs in Java 291
Spark Program Summary 295
Spark SQL 295
Basic Concepts 295
Using SparkSQL with RDDs 296
Spark Streaming 305
Basic Concepts 305
Creating Your First Stream with Scala 306
Creating Your First Stream with Java 309

MLib: The Machine Learning Library 311
Dependencies 311
Decision Trees 312
Clustering 313
Summary 313

Chapter 12 Machine Learning with R 315
Installing R 315
Mac OSX 315
Windows 316
Linux 316
Your First Run 316
Installing R-Studio 317
The R Basics 318
Variables and Vectors 318
Matrices 319
Lists 320
Data Frames 321
Installing Packages 322
Loading in Data 323
Plotting Data 324
Simple Statistics 327
Simple Linear Regression 329
Creating the Data 329
The Initial Graph 329
Regression with the Linear Model 330
Making a Prediction 331
Basic Sentiment Analysis 331
Functions to Load in Word Lists 331
Writing a Function to Score Sentiment 332
Testing the Function 333
Apriori Association Rules 333
Installing the ARules Package 334
The Training Data 334
Importing the Transaction Data 335
Running the Apriori Algorithm 336
Inspecting the Results 336
Accessing R from Java 337
Installing the rJava Package 337
Your First Java Code in R 337
Calling R from Java Programs 338
Setting Up an Eclipse Project 338
Creating the Java/R Class 339
Running the Example 340
Extending Your R Implementations 342
R and Hadoop 342

The RHadoop Project 342
A Sample Map Reduce Job in RHadoop 343
Connecting to Social Media with R 345
Summary 347

Appendix A SpringXD Quick Start 349
Installing Manually 349
Starting SpringXD 349
Creating a Stream 350
Adding a Twitter Application Key 350

Appendix B Hadoop 1.x Quick Start 351
Downloading and Installing Hadoop 351
Formatting the HDFS Filesystem 352
Starting and Stopping Hadoop 353
Process List of a Basic Job 353

Appendix C Useful Unix Commands 355
Using Sample Data 355
Showing the Contents: cat, more, and less 356
Example Command 356
Expected Output 356
Filtering Content: grep 357
Example Command for Finding Text 357
Example Output 357
Sorting Data: sort 358
Example Command for Basic Sorting 358
Example Output 358
Finding Unique Occurrences: uniq 360
Showing the Top of a File: head 361
Counting Words: wc 361
Locating Anything: find 362
Combining Commands and Redirecting Output 363
Picking a Text Editor 363
Colon Frenzy: Vi and Vim 363
Nano 364
Emacs 364

Appendix D Further Reading 367
Machine Learning 367
Statistics 368
Big Data and Data Science 368
Hadoop 368
Visualization 369
Making Decisions 369
Datasets 369
Blogs 370
Useful Websites 370
The Tools of the Trade 370

Index 373