Practical Data Science with R

NINA ZUMEL JOHN MOUNT



To our parents Olive and Paul Zumel Peggy and David Mount

brief contents

PART 1	INTRODUCTION TO DATA SCIENCE1
	1 • The data science process 3
	2 • Loading data into R 18
	3 • Exploring data 35
	4 Managing data 64
PART 2	MODELING METHODS81
	5 • Choosing and evaluating models 83
	6 • Memorization methods 115
	7 • Linear and logistic regression 140
	8 • Unsupervised methods 175
	9 Exploring advanced methods 211
PART 3	DELIVERING RESULTS
	10 • Documentation and deployment 255
	11 • Producing effective presentations 287

contents

foreword xv
preface xvii
acknowledgments xviii
about this book xix
about the cover illustration xxv

T	→	•
PART 1	INTRODUCTION TO DATA	SCIENCE

- The data science process 3
 - 1.1 The roles in a data science project 3

 Project roles 4
 - 1.2 Stages of a data science project 6

Defining the goal 7 • Data collection and management 8
Modeling 10 • Model evaluation and critique 11
Presentation and documentation 13 • Model deployment and
maintenance 14

- 1.3 Setting expectations 14

 Determining lower and upper bounds on model performance 15
- 1.4 Summary 17

X CONTENTS

O Loading data into R 18

	2.1	Working with data from files 19
		Working with well-structured data from files or URLs $$ 19 $$ Using R on less-structured data $$ 22
	2.2	Working with relational databases 24
		A production-size example 25 \bullet Loading data from a database into R 30 \bullet Working with the PUMS data 31
	2.3	Summary 34
2	Explorin	ng data 35
	3.1	Using summary statistics to spot problems 36
		Typical problems revealed by data summaries 38
	3.2	Spotting problems using graphics and visualization 41
		Visually checking distributions for a single variable 43 Visually checking relationships between two variables 51
	3.3	Summary 62
1	Managi	ng data 64
7	4.1	Cleaning data 64
		Treating missing values (NAs) 65 • Data transformations 69
	4.2	Sampling for modeling and validation 76
		Test and training splits 76 • Creating a sample group column 77 • Record grouping 78 • Data provenance 78
	4.3	Summary 79
PART 2	Moi	DELING METHODS81
5	Choosin	g and evaluating models 83
	5.1	Mapping problems to machine learning tasks 84
		Solving classification problems 85 • Solving scoring problems 87 • Working without known targets 88 Problem-to-method mapping 90
	5.2	Evaluating models 92
		Evaluating classification models 93 • Evaluating scoring models 98 • Evaluating probability models 101 • Evaluating ranking models 105 • Evaluating clustering models 105

CONTENTS xi

	5.3	Validating models 108
		Identifying common model problems 108 • Quantifying model soundness 110 • Ensuring model quality 111
	5.4	Summary 113
6	Memori	zation methods 115
O	6.1	KDD and KDD Cup 2009 116
		Getting started with KDD Cup 2009 data 117
	6.2	Building single-variable models 118
		Using categorical features 119 • Using numeric features 121 Using cross-validation to estimate effects of overfitting 123
	6.3	Building models using many variables 125
		Variable selection 125 • Using decision trees 127 • Using nearest neighbor methods 130 • Using Naive Bayes 134
	6.4	Summary 138
7	Linear o	and logistic regression 140
	7.1	Using linear regression 141
		Understanding linear regression 141 • Building a linear regression model 144 • Making predictions 145 • Finding relations and extracting advice 149 • Reading the model summary and characterizing coefficient quality 151 • Linear regression takeaways 156
	7.2	Using logistic regression 157
		Understanding logistic regression 157 • Building a logistic regression model 159 • Making predictions 160 • Finding relations and extracting advice from logistic models 164 Reading the model summary and characterizing coefficients 166 Logistic regression takeaways 173
	7.3	Summary 174
0	Unsuper	rvised methods 175
0	8.1	Cluster analysis 176
		Distances 176 • Preparing the data 178 • Hierarchical clustering with hclust() 180 • The k-means algorithm 190 Assigning new points to clusters 195 • Clustering takeaways 198

xii CONTENTS

8.2 Association rules 198

	Overview of association rules 199 • The example problem 200 Mining association rules with the arules package 201 Association rule takeaways 209
8.3	Summary 209
() Explori	ng advanced methods 211
9.1	Using bagging and random forests to reduce training variance 212
	Using bagging to improve prediction 213 • Using random forests to further improve prediction 216 • Bagging and random forest takeaways 220
9.2	Using generalized additive models (GAMs) to learn non- monotone relationships 221
	Understanding GAMs 221 • A one-dimensional regression example 222 • Extracting the nonlinear relationships 226 Using GAM on actual data 228 • Using GAM for logistic regression 231 • GAM takeaways 233
9.3	Using kernel methods to increase data separation 233
	Understanding kernel functions 234 • Using an explicit kernel on a problem 238 • Kernel takeaways 241
9.4	Using SVMs to model complicated decision boundaries 242
	Understanding support vector machines 242 • Trying an SVM on artificial example data 245 • Using SVMs on real data 248 Support vector machine takeaways 251
9.5	Summary 251
PART 3 DEL	IVERING RESULTS253
1 Docume	entation and deployment 255
10.1	The buzz dataset 256
10.2	Using knitr to produce milestone documentation 258 What is knitr? 258 • knitr technical details 261 • Using knitr to document the buzz data 262

CONTENTS xiii

10.3	Using comments and version control for running documentation 266
	Writing effective comments 266 • Using version control to record history 267 • Using version control to explore your project 272 Using version control to share work 276
10.4	Deploying models 280
	Deploying models as R HTTP services 280 • Deploying models by export 283 • What to take away 284
10.5	Summary 286
7 7 Produci	ng effective presentations 287
11.1	Presenting your results to the project sponsor 288
	Summarizing the project's goals 289 • Stating the project's results 290 • Filling in the details 292 • Making recommendations and discussing future work 294 Project sponsor presentation takeaways 295
11.2	Presenting your model to end users 295
	Summarizing the project's goals 296 • Showing how the model fits the users' workflow 296 • Showing how to use the model 299 End user presentation takeaways 300
11.3	Presenting your work to other data scientists 301
	Introducing the problem 301 • Discussing related work 302 Discussing your approach 302 • Discussing results and future work 303 • Peer presentation takeaways 304
11.4	Summary 304
appendix A	Working with R and other tools 307
appendix B	Important statistical concepts 333
$appendix\ C$	More tools and ideas worth exploring 369
	bibliography 375
	index 377