Contents

Preface		e		vii
1	Inti	Introduction		
2	Sta	tistical	l Learning	15
	2.1	What	Is Statistical Learning?	15
		2.1.1	Why Estimate f ?	17
		2.1.2	How Do We Estimate f ?	21
		2.1.3	The Trade-Off Between Prediction Accuracy	
			and Model Interpretability	24
		2.1.4	Supervised Versus Unsupervised Learning	26
		2.1.5	Regression Versus Classification Problems	28
	2.2	Assess	sing Model Accuracy	29
		2.2.1	Measuring the Quality of Fit	29
		2.2.2	The Bias-Variance Trade-Off	33
		2.2.3	The Classification Setting	37
	2.3	Lab: I	Introduction to R	42
		2.3.1	Basic Commands	42
		2.3.2	Graphics	45
		2.3.3	Indexing Data	47
		2.3.4	Loading Data	48
		2.3.5	Additional Graphical and Numerical Summaries	49
	2.4	Exerc	-	52

3	Lin		9
	3.1	Simple Linear Regression	31
			31
		3.1.2 Assessing the Accuracy of the Coefficient	
		Estimates	33
		3.1.3 Assessing the Accuracy of the Model 6	38
	3.2	Multiple Linear Regression	71
		3.2.1 Estimating the Regression Coefficients	72
		3.2.2 Some Important Questions	75
	3.3	Other Considerations in the Regression Model	32
		3.3.1 Qualitative Predictors	32
			36
		3.3.3 Potential Problems	92
	3.4	The Marketing Plan)2
	3.5	Comparison of Linear Regression with K-Nearest	
		Neighbors)4
	3.6	Lab: Linear Regression)9
		3.6.1 Libraries)9
		3.6.2 Simple Linear Regression	10
		3.6.3 Multiple Linear Regression	13
		3.6.4 Interaction Terms	15
		3.6.5 Non-linear Transformations of the Predictors 11	15
		3.6.6 Qualitative Predictors	17
		3.6.7 Writing Functions	19
	3.7	Exercises	20
4	Cla	ssification 12	27
	4.1	An Overview of Classification	28
	4.2	Why Not Linear Regression?	29
	4.3	Logistic Regression	30
		4.3.1 The Logistic Model	31
		4.3.2 Estimating the Regression Coefficients	33
		4.3.3 Making Predictions	34
		4.3.4 Multiple Logistic Regression	35
		4.3.5 Logistic Regression for >2 Response Classes 13	37
	4.4	Linear Discriminant Analysis	38
		4.4.1 Using Bayes' Theorem for Classification 13	38
		4.4.2 Linear Discriminant Analysis for $p = 1 \dots 13$	39
		4.4.3 Linear Discriminant Analysis for $p > 1 \dots 14$	12
			19
	4.5	A Comparison of Classification Methods	51
	4.6	Lab: Logistic Regression, LDA, QDA, and KNN 15	54
		4.6.1 The Stock Market Data	54
		4.6.2 Logistic Regression	56
		4.6.3 Linear Discriminant Analysis 16	31

		4.6.4 $4.6.5$	Quadratic Discriminant Analysis K -Nearest Neighbors	162 163
	4.7	4.6.6 Exerci	An Application to Caravan Insurance Data ises	164 168
5	Res	amplir	ng Methods	175
	5.1	Cross-	-Validation	176
		5.1.1	The Validation Set Approach	176
		5.1.2	Leave-One-Out Cross-Validation	178
		5.1.3	k-Fold Cross-Validation	181
		5.1.4	Bias-Variance Trade-Off for k -Fold	
			Cross-Validation	183
		5.1.5	Cross-Validation on Classification Problems	184
	5.2	The B	Bootstrap	187
	5.3	Lab: (Cross-Validation and the Bootstrap	190
		5.3.1	The Validation Set Approach	191
		5.3.2	Leave-One-Out Cross-Validation	192
		5.3.3	k-Fold Cross-Validation	193
		5.3.4	The Bootstrap	194
	5.4	Exerci	ises	197
6	Line	ear Mo	odel Selection and Regularization	203
	6.1	Subset	t Selection	205
		6.1.1	Best Subset Selection	205
		6.1.2	Stepwise Selection	207
		6.1.3	Choosing the Optimal Model	210
	6.2	Shrink	Rage Methods	214
		6.2.1	Ridge Regression	215
		6.2.2	The Lasso	219
		6.2.3	Selecting the Tuning Parameter	227
	6.3	Dimer	nsion Reduction Methods	228
		6.3.1	Principal Components Regression	230
		6.3.2	Partial Least Squares	237
	6.4	Consid	derations in High Dimensions	238
		6.4.1	High-Dimensional Data	238
		6.4.2	What Goes Wrong in High Dimensions?	239
		6.4.3	Regression in High Dimensions	241
		6.4.4	Interpreting Results in High Dimensions	243
	6.5	Lab 1:	: Subset Selection Methods	244
		6.5.1	Best Subset Selection	244
		6.5.2	Forward and Backward Stepwise Selection	247
		6.5.3	Choosing Among Models Using the Validation	
			Set Approach and Cross-Validation	248

	6.6	6.6.1 Ridge Regression	251 251
			255
	6.7	Lab 3: PCR and PLS Regression	256
			256
		±	258
	6.8	Exercises	259
7			265
	7.1	v	266
	7.2	*	268
	7.3		270
	7.4	0 1	271
		·	271
		±	271
		1 1	273
		7.4.4 Choosing the Number and Locations	O = 4
			274
		1 0	276
	7.5	0 1	277
		0 1	277
	7 C	e e	278
	$7.6 \\ 7.7$		$\frac{280}{282}$
	1.1		
		O .	283 286
	7 9		280 287
	7.8	e e e e e e e e e e e e e e e e e e e	288
		·	200 293
		1	293 294
	7.9		$294 \\ 297$
	1.9	EXCICISES	49 I
8			303
	8.1		303
		9	304
			311
			314
	0.0		315
	8.2	7 9	316
		66 6	316
			320
	0.0		321
	8.3		324
			324
		8.3.2 Fitting Regression Trees	327

		Contents	xiii
		8.3.3 Bagging and Random Forests	328
		8.3.4 Boosting	330
	8.4	Exercises	332
0	C	want Markan Markina	225
9	9.1	port Vector Machines	337 338
	9.1	Maximal Margin Classifier	338
		*	339
		9.1.2 Classification Using a Separating Hyperplane9.1.3 The Maximal Margin Classifier	341
		9.1.4 Construction of the Maximal Margin Classifier	$341 \\ 342$
		9.1.5 The Non-separable Case	343
	9.2	Support Vector Classifiers	344
	9.2	* *	$\frac{344}{344}$
		11	$\frac{344}{345}$
	0.2	11	$\frac{345}{349}$
	9.3	Support Vector Machines	549
		Boundaries	349
		9.3.2 The Support Vector Machine	350
		9.3.3 An Application to the Heart Disease Data	354
	9.4	SVMs with More than Two Classes	354
	9.4	9.4.1 One-Versus-One Classification	355
		9.4.2 One-Versus-All Classification	356
	9.5	Relationship to Logistic Regression	356
	9.6	Lab: Support Vector Machines	359
	3.0	9.6.1 Support Vector Classifier	359
		9.6.2 Support Vector Machine	363
		9.6.3 ROC Curves	365
		9.6.4 SVM with Multiple Classes	366
		9.6.5 Application to Gene Expression Data	366
	9.7	Exercises	368
	5.1	LACTORES	300
10		upervised Learning	373
		The Challenge of Unsupervised Learning	
	10.2	Principal Components Analysis	
		10.2.1 What Are Principal Components?	375
		10.2.2 Another Interpretation of Principal Components	379
		10.2.3 More on PCA	380
		10.2.4 Other Uses for Principal Components	385
	10.3	Clustering Methods	385
		10.3.1 K-Means Clustering	386
		10.3.2 Hierarchical Clustering	390
		10.3.3 Practical Issues in Clustering	399
	10.4	Lab 1: Principal Components Analysis	401

xiv Contents

10.6 Lab 3: NCI60 Data Example
10.6.2 Clustering the Observations of the NCI60 Data 410 10.7 Exercises
Index 41s