

Contents

Part I Descriptive Techniques

1	Comparison of Batches	3
1.1	Boxplots	4
1.2	Histograms	11
1.3	Kernel Densities	15
1.4	Scatterplots	19
1.5	Chernoff-Flury Faces	22
1.6	Andrews' Curves	29
1.7	Parallel Coordinates Plots	32
1.8	Hexagon Plots	37
1.9	Boston Housing	40
1.10	Exercises	48

Part II Multivariate Random Variables

2	A Short Excursion into Matrix Algebra	53
2.1	Elementary Operations	53
2.2	Spectral Decompositions	60
2.3	Quadratic Forms	62
2.4	Derivatives	65
2.5	Partitioned Matrices	66
2.6	Geometrical Aspects	68
2.7	Exercises	76
3	Moving to Higher Dimensions	79
3.1	Covariance	80
3.2	Correlation	84
3.3	Summary Statistics	89
3.4	Linear Model for Two Variables	93
3.5	Simple Analysis of Variance	100

3.6	Multiple Linear Model	105
3.7	Boston Housing	110
3.8	Exercises	113
4	Multivariate Distributions	117
4.1	Distribution and Density Function	118
4.2	Moments and Characteristic Functions	123
4.3	Transformations	135
4.4	The Multinormal Distribution	137
4.5	Sampling Distributions and Limit Theorems	142
4.6	Heavy-Tailed Distributions	149
4.7	Copulae	166
4.8	Bootstrap	176
4.9	Exercises	179
5	Theory of the Multinormal	183
5.1	Elementary Properties of the Multinormal	183
5.2	The Wishart Distribution	191
5.3	Hotelling's T^2 -Distribution	193
5.4	Spherical and Elliptical Distributions	195
5.5	Exercises	197
6	Theory of Estimation	201
6.1	The Likelihood Function	202
6.2	The Cramer–Rao Lower Bound	206
6.3	Exercises	210
7	Hypothesis Testing	213
7.1	Likelihood Ratio Test	214
7.2	Linear Hypothesis	224
7.3	Boston Housing	242
7.4	Exercises	246

Part III Multivariate Techniques

8	Regression Models	253
8.1	General ANOVA and ANCOVA Models	255
	8.1.1 ANOVA Models	255
	8.1.2 ANCOVA Models	260
	8.1.3 Boston Housing	262
8.2	Categorical Responses	263
	8.2.1 Multinomial Sampling and Contingency Tables	263
	8.2.2 Log-Linear Models for Contingency Tables	264
	8.2.3 Testing Issues with Count Data	268
	8.2.4 Logit Models	271
8.3	Exercises	279

9	Variable Selection	281
9.1	Lasso.....	282
9.1.1	Lasso in the Linear Regression Model	282
9.1.2	Lasso in High Dimensions	292
9.1.3	Lasso in Logit Model.....	293
9.2	Elastic Net.....	297
9.2.1	Elastic Net in Linear Regression Model	298
9.2.2	Elastic Net in Logit Model	299
9.3	Group Lasso.....	300
9.4	Exercises	304
10	Decomposition of Data Matrices by Factors	305
10.1	The Geometric Point of View	306
10.2	Fitting the p -Dimensional Point Cloud	307
10.3	Fitting the n -Dimensional Point Cloud	310
10.4	Relations Between Subspaces	312
10.5	Practical Computation	314
10.6	Exercises	317
11	Principal Components Analysis	319
11.1	Standardised Linear Combination.....	320
11.2	Principal Components in Practice	324
11.3	Interpretation of the PCs.....	327
11.4	Asymptotic Properties of the PCs	331
11.5	Normalised Principal Components Analysis	335
11.6	Principal Components as a Factorial Method.....	336
11.7	Common Principal Components	342
11.8	Boston Housing	346
11.9	More Examples	348
11.10	Exercises	357
12	Factor Analysis	359
12.1	The Orthogonal Factor Model.....	360
12.2	Estimation of the Factor Model	367
12.3	Factor Scores and Strategies.....	376
12.4	Boston Housing	378
12.5	Exercises	382
13	Cluster Analysis	385
13.1	The Problem.....	386
13.2	The Proximity Between Objects	387
13.3	Cluster Algorithms.....	392
13.4	Boston Housing	400
13.5	Exercises	404

14	Discriminant Analysis	407
14.1	Allocation Rules for Known Distributions	407
14.2	Discrimination Rules in Practice	415
14.3	Boston Housing	421
14.4	Exercises	423
15	Correspondence Analysis	425
15.1	Motivation	426
15.2	Chi-Square Decomposition	428
15.3	Correspondence Analysis in Practice	432
15.4	Exercises	441
16	Canonical Correlation Analysis	443
16.1	Most Interesting Linear Combination	443
16.2	Canonical Correlation in Practice	448
16.3	Exercises	454
17	Multidimensional Scaling	455
17.1	The Problem	455
17.2	Metric MDS	460
17.3	Nonmetric MDS	465
17.4	Exercises	472
18	Conjoint Measurement Analysis	473
18.1	Introduction	473
18.2	Design of Data Generation	475
18.3	Estimation of Preference Orderings	478
18.4	Exercises	485
19	Applications in Finance	487
19.1	Portfolio Choice	487
19.2	Efficient Portfolio	488
19.3	Efficient Portfolios in Practice	496
19.4	The Capital Asset Pricing Model	497
19.5	Exercises	499
20	Computationally Intensive Techniques	501
20.1	Simplicial Depth	502
20.2	Projection Pursuit	505
20.3	Sliced Inverse Regression	511
20.4	Support Vector Machines	519
20.5	Classification and Regression Trees	534
20.6	Boston Housing	552
20.7	Exercises	554

Part IV Appendix

21	Symbols and Notations	557
22	Data	561
22.1	Boston Housing Data	561
22.2	Swiss Bank Notes	562
22.3	Car Data	562
22.4	Classic Blue Pullovers Data	563
22.5	US Companies Data	563
22.6	French Food Data	563
22.7	Car Marks	564
22.8	French Baccalauréat Frequencies	564
22.9	Journaux Data	564
22.10	US Crime Data	565
22.11	Plasma Data	566
22.12	WAIS Data	566
22.13	ANOVA Data	567
22.14	Timebudget Data	567
22.15	Geopol Data	568
22.16	US Health Data	569
22.17	Vocabulary Data	570
22.18	Athletic Records Data	570
22.19	Unemployment Data	570
22.20	Annual Population Data	570
22.21	Bankruptcy Data I	571
22.22	Bankruptcy Data II	571
	References	573
	Index	577