Contents

	Preface	page 1X
PΑ	RT ONE: INTRODUCTION	
1.	Introduction	3
1.1	Examples	3
1.2	Notation	5
1.3	Review of objectives and different approaches	6
1.4	Some general comments	9
1.5	Review of books on multivariate analysis	10
1.6	Some matrix algebra revision	11
1.7	The general linear model	15
	Exercises	17
2.	Multivariate distributions	18
2.1	Multivariate, marginal and conditional distributions	18
2.2	Means, variances, covariances and correlations	23
2.3	The multivariate normal distribution	28
2.4	The bivariate normal distribution	29
2.5	Other multivariate distributions	31
	2.5.1 Multivariate discrete distributions	31
	2.5.2 Multivariate continuous distributions	31
	Exercises	32
3.	Preliminary data analysis	34
3.1	Processing the data	34
	3.1.1 Data editing	36
3.2	Calculating summary statistics	38
	3.2.1 Interpreting the sample correlation matrix	40
	3.2.2 The rank of R	48
3.3	Plotting the data	49
3.4	The analysis of discrete data	51
	Exercises	53

_vi Contents

PA	RT TWO: FINDING NEW UNDERLYING VARIABI	LES
4.	Principal component analysis	5′
4.1	Introduction	5
4.2	Derivation of principal components	5
	4.2.1 Principal components from the correlation matrix	6
	4.2.2 Estimating the principal components	6.
4.3	Further results on PCA.	63
	4.3.1 Mean-corrected component scores	6
	4.3.2 The inverse transformation	64
	4.3.3 Zero eigenvalues	64
	4.3.4 Small eigenvalues	64
	4.3.5 Repeated roots	6:
	4.3.6 Orthogonality	60
	4.3.7 Component loadings/component correlations	60
	4.3.8 Off-diagonal structure	6
	4.3.9 Uncorrelated variables	68
4.4	The problem of scaling in PCA	68
4.5	Discussion	7
	4.5.1 The identification of important components	72
1.0	4.5.2 The use of components in subsequent analyses	7:
4.6	PCA for multivariate normal data	7
4.7	Summary	78
	Exercises	79
5.	Factor analysis	82
5.1	Introduction	82
5.2	The factor-analysis model	83
5.3	Estimating the factor loadings	86
5.4	Discussion	87
D A	RT THREE: PROCEDURES BASED ON THE	
	ULTIVARIATE NORMAL DISTRIBUTION	
IVI	CLITARIATE NORMAL DISTRIBUTION	
6.	The multivariate normal distribution	93
6.1	Introduction	93
6.2	Definition of the multivariate normal distribution	93
6.3	Properties of the multivariate normal distribution	97
6.4	Linear compounds and linear combinations	101
6.5	Estimation of the parameters of the distribution	103
6.6	The Wishart distribution	104
6.7	The joint distribution of the sample mean vector and the sample	
	covariance matrix	107
6.8	The Hotelling T^2 -distribution	108
	Evercises	111

Contents	Vi

7.	Procedures based on normal distribution theory	114
7.1	Introduction	114
7.2	One-sample procedures	114
7.3	Confidence intervals and further analysis	117
7.4	Tests of structural relations among the components of the mean	122
7.5	Two-sample procedures	124
7.6	Confidence intervals and further analysis	125
7.7	Tests of structural relations among the components of the means	129
7.8	Discriminant analysis	133
	Exercises	138
8.	The multivariate analysis of variance	140
8.1	Introduction	140
8.2	MANOVA calculations	140
8.3	Testing hypotheses	144
	8.3.1 The special case: The univariate procedure	144
	8.3.2 The multivariate model for Example 8.1	145
	8.3.3 Multivariate test procedures	146
	8.3.4 Distributional approximations	148
	8.3.5 Applications of the methodology	149
8.4	Further analysis	151
8.5	The dimensionality of the alternative hypothesis	152
8.6	Canonical variates analysis	153
8.7	Linear functional relationships	159
8.8	Discriminant analysis	160
	Exercises	160
9.	The multivariate analysis of covariance and related topics	162
9.1	Introduction	162
9.2	Multivariate regression	162
	9.2.1 The special case: Univariate multiple regression	163
	9.2.2 The general case: Multivariate regression	165
9.3	Canonical correlation.	169
9.4	The multivariate analysis of covariance	173
	9.4.1 The special case: Univariate analysis of covariance	173
	9.4.2 The multivariate case: An example	176
	9.4.3 The multivariate case: General results	178
9.5	The test for additional information	180
9.6	A test of an assigned subset of linear compounds	184
	Exercises	186

viii Contents

PART	FOUR:	MULTID	IMENSIONAL	SCALING	AND
CLUS	TER AN	ALVSIS			

10.	Multidimensional scaling.	189		
10.1	Introduction	189		
10.2	Measures of similarity and dissimilarity			
	10.2.1 Similarity coefficients for binary data	194		
10.3	Classical scaling	198		
	10.3.1 The calculation of co-ordinate values from Euclidean			
	distances	198		
	10.3.2 The relationship between classical scaling and principal com-	200		
	ponent analysis	200		
	10.3.3 Classical scaling for a dissimilarity matrix 10.3.4 Interpretation of the results	201 202		
	10.3.5 Some related methods	204		
10.4	Ordinal scaling	204		
10.4	10.4.1 The iterative procedure	205		
	10.4.2 Interpreting the results	208		
10.5	A comparison	209		
	Concluding remarks	210		
	Exercises	210		
11.	Cluster analysis	212		
	Introduction	212		
	11.1.1 Objectives	214		
	11.1.2 Clumping, dissection and clustering variables	21:		
	11.1.3 Some other preliminary points	215		
11.2	Visual approaches to finding a partition	216		
	Hierarchical trees	219		
11.4	Single-link clustering	220		
11.5	Some other clustering procedures	224		
	11.5.1 Method or algorithm?	226		
11.6	A comparison of procedures	226		
	11.6.1 Some desirable conditions for hierarchical clustering methods	226		
	11.6.2 A comparison	227		
	Exercises	229		
	References	231		
	Answers to exercises	235		
	Alishers to carrises	233		
	Name Index	241		
	Subject Index	243		