
CONTENTS

PREFACE	xi
ACKNOWLEDGMENTS	xv
LIST OF TABLES	xvii
1 INTRODUCTION	1
1.1 Historical Background	1
1.2 Definition and Relationship to the Delta Method and Other Resampling Methods	3
1.2.1 Jackknife	6
1.2.2 Delta Method	7
1.2.3 Cross-Validation	7
1.2.4 Subsampling	8
1.3 Wide Range of Applications	8
1.4 The Bootstrap and the R Language System	10
1.5 Historical Notes	25
1.6 Exercises	26
References	27
2 ESTIMATION	30
2.1 Estimating Bias	30
2.1.1 Bootstrap Adjustment	30
2.1.2 Error Rate Estimation in Discriminant Analysis	32
2.1.3 Simple Example of Linear Discrimination and Bootstrap Error Rate Estimation	42
2.1.4 Patch Data Example	51
2.2 Estimating Location	53
2.2.1 Estimating a Mean	53
2.2.2 Estimating a Median	54
2.3 Estimating Dispersion	54
2.3.1 Estimating an Estimate's Standard Error	55
2.3.2 Estimating Interquartile Range	56

2.4	Linear Regression	56
2.4.1	Overview	56
2.4.2	Bootstrapping Residuals	57
2.4.3	Bootstrapping Pairs (Response and Predictor Vector)	58
2.4.4	Heteroscedasticity of Variance: The Wild Bootstrap	58
2.4.5	A Special Class of Linear Regression Models: Multivariable Fractional Polynomials	60
2.5	Nonlinear Regression	60
2.5.1	Examples of Nonlinear Models	61
2.5.2	A Quasi-Optical Experiment	63
2.6	Nonparametric Regression	63
2.6.1	Examples of Nonparametric Regression Models	64
2.6.2	Bootstrap Bagging	66
2.7	Historical Notes	67
2.8	Exercises	69
	References	71
3	CONFIDENCE INTERVALS	76
3.1	Subsampling, Typical Value Theorem, and Efron's Percentile Method	77
3.2	Bootstrap- <i>t</i>	79
3.3	Iterated Bootstrap	83
3.4	Bias-Corrected (BC) Bootstrap	85
3.5	BCa and ABC	85
3.6	Tilted Bootstrap	88
3.7	Variance Estimation with Small Sample Sizes	90
3.8	Historical Notes	94
3.9	Exercises	96
	References	98
4	HYPOTHESIS TESTING	101
4.1	Relationship to Confidence Intervals	103
4.2	Why Test Hypotheses Differently?	105
4.3	Tendril DX Example	106
4.4	Klingenberg Example: Binary Dose–Response	108
4.5	Historical Notes	109
4.6	Exercises	110
	References	111

5 TIME SERIES	113
5.1 Forecasting Methods	113
5.2 Time Domain Models	114
5.3 Can Bootstrapping Improve Prediction Intervals?	115
5.4 Model-Based Methods	118
5.4.1 Bootstrapping Stationary Autoregressive Processes	118
5.4.2 Bootstrapping Explosive Autoregressive Processes	123
5.4.3 Bootstrapping Unstable Autoregressive Processes	123
5.4.4 Bootstrapping Stationary ARMA Processes	123
5.5 Block Bootstrapping for Stationary Time Series	123
5.6 Dependent Wild Bootstrap (DWB)	126
5.7 Frequency-Based Approaches for Stationary Time Series	127
5.8 Sieve Bootstrap	128
5.9 Historical Notes	129
5.10 Exercises	131
References	131
6 BOOTSTRAP VARIANTS	136
6.1 Bayesian Bootstrap	137
6.2 Smoothed Bootstrap	138
6.3 Parametric Bootstrap	139
6.4 Double Bootstrap	139
6.5 The m -Out-of- n Bootstrap	140
6.6 The Wild Bootstrap	141
6.7 Historical Notes	141
6.8 Exercises	142
References	142
7 CHAPTER SPECIAL TOPICS	144
7.1 Spatial Data	144
7.1.1 Kriging	144
7.1.2 Asymptotics for Spatial Data	147
7.1.3 Block Bootstrap on Regular Grids	148
7.1.4 Block Bootstrap on Irregular Grids	148
7.2 Subset Selection in Regression	148
7.2.1 Gong's Logistic Regression Example	149
7.2.2 Gunter's Qualitative Interaction Example	153
7.3 Determining the Number of Distributions in a Mixture	155

7.4	Censored Data	157
7.5	<i>P</i> -Value Adjustment	158
7.5.1	The Westfall–Young Approach	159
7.5.2	Passive Plus Example	159
7.5.3	Consulting Example	160
7.6	Bioequivalence	162
7.6.1	Individual Bioequivalence	162
7.6.2	Population Bioequivalence	165
7.7	Process Capability Indices	165
7.8	Missing Data	172
7.9	Point Processes	174
7.10	Bootstrap to Detect Outliers	176
7.11	Lattice Variables	177
7.12	Covariate Adjustment of Area Under the Curve Estimates for Receiver Operating Characteristic (ROC) Curves	177
7.13	Bootstrapping in SAS	179
7.14	Historical Notes	182
7.15	Exercises	183
	References	185
8	WHEN THE BOOTSTRAP IS INCONSISTENT AND HOW TO REMEDY IT	190
8.1	Too Small of a Sample Size	191
8.2	Distributions with Infinite Second Moments	191
8.2.1	Introduction	191
8.2.2	Example of Inconsistency	192
8.2.3	Remedies	193
8.3	Estimating Extreme Values	194
8.3.1	Introduction	194
8.3.2	Example of Inconsistency	194
8.3.3	Remedies	194
8.4	Survey Sampling	195
8.4.1	Introduction	195
8.4.2	Example of Inconsistency	195
8.4.3	Remedies	195
8.5	<i>m</i> -Dependent Sequences	196
8.5.1	Introduction	196
8.5.2	Example of Inconsistency When Independence Is Assumed	196
8.5.3	Remedy	197

8.6	Unstable Autoregressive Processes	197
8.6.1	Introduction	197
8.6.2	Example of Inconsistency	197
8.6.3	Remedies	197
8.7	Long-Range Dependence	198
8.7.1	Introduction	198
8.7.2	Example of Inconsistency	198
8.7.3	A Remedy	198
8.8	Bootstrap Diagnostics	199
8.9	Historical Notes	199
8.10	Exercises	201
	References	201
	AUTHOR INDEX	204
	SUBJECT INDEX	210