## **Contents**

Preface		xiii	
1.	Intro	duction	1
	1.1.	Advantages of Nonparametric Methods 1	
	1.2.	The Distribution-Free Property 2	
	1.3.	Some Real-World Applications 3	
	1.4.	Format and Organization 6	
	1.5.	Computing with R 8	
	1.6.	Historical Background 9	
2.	The 1	Dichotomous Data Problem	11
		Introduction 11	
	2.1.	A Binomial Test 11	
	2.2.	An Estimator for the Probability of Success 22	
	2.3.	A Confidence Interval for the Probability of Success (Wilson) 24	
	2.4.	Bayes Estimators for the Probability of Success 33	
3.	The	One-Sample Location Problem	39
		Introduction 39	
		Paired Replicates Analyses by Way of Signed Ranks 39	
	3.1.	A Distribution-Free Signed Rank Test (Wilcoxon) 40	
	3.2.	An Estimator Associated with Wilcoxon's Signed Rank Statistic	
		(Hodges–Lehmann) 56	
	3.3.	A Distribution-Free Confidence Interval Based on Wilcoxon's Signed Rank Test	
		(Tukey) 59	
		Paired Replicates Analyses by Way of Signs 63	
	3.4.	A Distribution-Free Sign Test (Fisher) 63	
	3.5.	An Estimator Associated with the Sign Statistic (Hodges–Lehmann) 76	
<b>→</b>	3.6.	A Distribution-Free Confidence Interval Based on the Sign Test (Thompson,	
		Savur) 80	
		One-Sample Data 84	
	3.7.	Procedures Based on the Signed Rank Statistic 84	
	3.8.	Procedures Based on the Sign Statistic 90	
	3.9.	An Asymptotically Distribution-Free Test of Symmetry	
		(Randles-Fligner-Policello-Wolfe, Davis-Quade) 94	
	2.10	Bivariate Data 102	
	3.10.	A Distribution-Free Test for Bivariate Symmetry (Hollander) 102	

3.11. Efficiencies of Paired Replicates and One-Sample Location Procedures

112

4. The Two-Sample Location Problem

	Introduction 115	
4.1.	A Distribution-Free Rank Sum Test (Wilcoxon, Mann and Whitney) 115	
4.2.	An Estimator Associated with Wilcoxon's Rank Sum Statistic	
	(Hodges-Lehmann) 136	
4.3.	A Distribution-Free Confidence Interval Based on Wilcoxon's Rank Sum Tes	t
	(Moses) 142	
4.4.	A Robust Rank Test for the Behrens–Fisher Problem (Fligner–Policello)	145
4.5.	Efficiencies of Two-Sample Location Procedures 149	
5. The	Two-Sample Dispersion Problem and Other Two-Sample Problems	151
<i>5</i> 1	Introduction 151	
5.1.	A Distribution-Free Rank Test for Dispersion–Medians Equal	
5.2.	(Ansari–Bradley) 152 An Asymptotically Distribution-Free Test for Dispersion Based on the	
5.4.	Jackknife–Medians Not Necessarily Equal (Miller) 169	
5.3.	A Distribution-Free Rank Test for Either Location or Dispersion (Lepage)	181
5.4.	A Distribution-Free Test for General Differences in Two Populations	101
	(Kolmogorov–Smirnov) 190	
5.5.	Efficiencies of Two-Sample Dispersion	
	and Broad Alternatives Procedures 200	
6. The	One-Way Layout	202
	Introduction 202	
6.1.	A Distribution-Free Test for General Alternatives (Kruskal–Wallis) 204	
6.2.	A Distribution-Free Test for Ordered Alternatives (Jonckheere-Terpstra)	215
	Distribution-Free Tests for Umbrella Alternatives (Mack–Wolfe) 225	
6.3A.	A Distribution-Free Test for Umbrella Alternatives, Peak Known	
	(Mack–Wolfe) 226	
6.3B.	A Distribution-Free Test for Umbrella Alternatives, Peak Unknown	
6.1	(Mack-Wolfe) 241	249
6.4.	A Distribution-Free Test for Treatments Versus a Control (Fligner–Wolfe) Rationale For Multiple Comparison Procedures 255	249
6.5.	Distribution-Free Two-Sided All-Treatments Multiple Comparisons Based on	Pairwice
0.5.		256
6.6.		
	Rankings-Ordered Treatment Effects (Hayter–Stone) 265	
6.7.		s Based
	on Joint Rankings (Nemenyi, Damico–Wolfe) 271	
6.8.	Contrast Estimation Based on Hodges-Lehmann Two-Sample Estimators	
	(Spjøtvoll) 278	
6.9.	Simultaneous Confidence Intervals for All Simple Contrasts	
	(Critchlow–Fligner) 282	
6.10.	Efficiencies of One-Way Layout Procedures 287	
	T	
7. The	Two-Way Layout	289

7.1. A Distribution-Free Test for General Alternatives in a Randomized Complete Block

115

Introduction

289

Design (Friedman, Kendall-Babington Smith)

	Contents ix
7.2.	A Distribution-Free Test for Ordered Alternatives in a Randomized Complete Block Design (Page) 304
	Rationale for Multiple Comparison Procedures 315
7.3.	Distribution-Free Two-Sided All-Treatments Multiple Comparisons Based on
	Friedman Rank Sums-General Configuration (Wilcoxon, Nemenyi,
	McDonald-Thompson) 316
7.4.	Distribution-Free One-Sided Treatments Versus Control Multiple Comparisons Based
	on Friedman Rank Sums (Nemenyi, Wilcoxon-Wilcox, Miller) 322
7.5.	Contrast Estimation Based on One-Sample Median Estimators (Doksum) 328
	Incomplete Block Data-Two-Way Layout with Zero or One Observation Per
	Treatment–Block Combination 331
7.6.	A Distribution-Free Test for General Alternatives in a Randomized Balanced
	Incomplete Block Design (BIBD) (Durbin-Skillings-Mack) 332
7.7.	Asymptotically Distribution-Free Two-Sided All-Treatments Multiple Comparisons
	for Balanced Incomplete Block Designs (Skillings–Mack) 341
7.8.	A Distribution-Free Test for General Alternatives for Data From an Arbitrary
	Incomplete Block Design (Skillings–Mack) 343
	Replications-Two-Way Layout with at Least One Observation for Every
	Treatment–Block Combination 354
7.9.	Č
	with an Equal Number $c(>1)$ of Replications Per Treatment–Block Combination
	(Mack–Skillings) 354
7.10.	Asymptotically Distribution-Free Two-Sided All-Treatments Multiple Comparisons
	for a Two-Way Layout with an Equal Number of Replications in Each
	Treatment–Block Combination (Mack–Skillings) 367
	Analyses Associated with Signed Ranks 370
7.11.	A Test Based on Wilcoxon Signed Ranks for General Alternatives in a Randomized
	Complete Block Design (Doksum) 370
7.12.	A Test Based on Wilcoxon Signed Ranks for Ordered Alternatives in a Randomized
<b>5.10</b>	Complete Block Design (Hollander) 376
7.13.	Approximate Two-Sided All-Treatments Multiple Comparisons Based on Signed

- d
- 379 Ranks (Nemenyi)
- Approximate One-Sided Treatments-Versus-Control Multiple Comparisons Based on Signed Ranks (Hollander)
- 7.15. Contrast Estimation Based on the One-Sample Hodges-Lehmann Estimators (Lehmann)
- 7.16. Efficiencies of Two-Way Layout Procedures 390

## 8. The Independence Problem

393

Introduction 3
----------------

- 8.1. A Distribution-Free Test for Independence Based on Signs (Kendall)
- An Estimator Associated with the Kendall Statistic (Kendall) 8.2.
- An Asymptotically Distribution-Free Confidence Interval Based on the Kendall Statistic (Samara-Randles, Fligner-Rust, Noether)
- An Asymptotically Distribution-Free Confidence Interval Based on Efron's 8.4. Bootstrap
- A Distribution-Free Test for Independence Based on Ranks (Spearman) 427 8.5.
- A Distribution-Free Test for Independence Against Broad Alternatives 8.6. (Hoeffding) 442
- 8.7. Efficiencies of Independence Procedures 450

9.	Regr	ession Problems	451
		Introduction 451	
		One Regression Line 452	
	9.1.	A Distribution-Free Test for the Slope of the Regression Line (Theil) 452	
	9.2.		
	9.3.	-	
		(Theil) 460	
	9.4.	An Intercept Estimator Associated with the Theil Statistic and Use of the Esti	imated
		-	163
		$k(\geq 2)$ Regression Lines 466	
	9.5.	An Asymptotically Distribution-Free Test for the Parallelism of Several Regre	ession
		Lines (Sen, Adichie) 466	
		General Multiple Linear Regression 475	
	9.6.		ear
		Regression (Jaeckel, Hettmansperger–McKean) 475	
		Nonparametric Regression Analysis 490	
	9.7.	An Introduction to Non-Rank-Based Approaches to Nonparametric Regression	n
		Analysis 490	
	9.8.	Efficiencies of Regression Procedures 494	
10.	Com	paring Two Success Probabilities	495
	Com	paring 100 baccess 110babinaes	170
		Introduction 495	
	10.1.	Approximate Tests and Confidence Intervals for the Difference between Two	Success
		Probabilities (Pearson) 496	
	10.2.		511
	10.3.		
	10.4.	,	
	10.5.	Efficiencies 534	
11.	Life	Distributions and Survival Analysis	535
		Introduction 535	
	11.1.	1 3	5.45
	11.2.		545
	11.3. 11.4.		555
	11.4.	(Guess-Hollander-Proschan) 563	
	11.5.		
	11.6.	An Estimator of the Distribution Function When the Data are Censored	
	11.0.	(Kaplan–Meier) 578	
	11.7.	A Two-Sample Test for Censored Data (Mantel) 594	
	11.8.	Efficiencies 605	
	_		
12.	Dens	ity Estimation	609
		Introduction 609	
	12.1.	Density Functions and Histograms 609	
	12.2.	Kernel Density Estimation 617	
	12.3.	Bandwidth Selection 624	
	12.4.	Other Methods 628	

13.	Wave	elets 629
	13.1.	Introduction 629 Wavelet Representation of a Function 630
	13.2. 13.3.	Wavelet Thresholding 644
14.	Smoo	othing 656
		Introduction 656
	14.1.	Local Averaging (Friedman) 657
		Local Regression (Cleveland) 662
		Kernel Smoothing 667
	14.4.	-
15.	Rank	ted Set Sampling 676
		Introduction 676
	15.1.	Rationale and Historical Development 676
	15.2.	
	15.3.	
	15.4.	Ranked Set Sample Analogs of the Mann–Whitney–Wilcoxon Two-Sample Procedures (Bohn–Wolfe) 717
	15.5.	Other Important Issues for Ranked Set Sampling 737
	15.6.	Extensions and Related Approaches 742
16.	An I Proce	Introduction to Bayesian Nonparametric Statistics via the Dirichlet less 744
		Introduction 744
	16.1.	
	16.2.	-
	16.3.	•
	16.4.	
	16.5.	
D.I		
Bib	oliogra	phy 763
R I	Progra	nm Index 791
	<i>.</i> 1 •	1 700
Au	thor I	ndex 799
Sul	oject I	index 809