Contents

Preface vii

1 Introduction 1
1.1 Survival data 1
1.2 Longitudinal data 14

2 Probabilistic background 17
2.1 Preliminaries 17
2.2 Martingales 20
2.3 Counting processes 23
2.4 Marked point processes 30
2.5 Large-sample results 34
2.6 Exercises 44

3 Estimation for filtered counting process data 49
3.1 Filtered counting process data 49
3.2 Likelihood constructions 62
3.3 Estimating equations 70
3.4 Exercises 74

4 Nonparametric procedures for survival data 81
4.1 The Kaplan-Meier estimator 81
4.2 Hypothesis testing 86
4.2.1 Comparisons of groups of survival data 86

4.2.2 Stratified tests 93
4.3 Exercises 95

5 Additive Hazards Models **103**
5.1 Additive hazards models 108
5.2 Inference for additive hazards models 116
5.3 Semiparametric additive hazards models 126
5.4 Inference for the semiparametric hazards model 135
5.5 Estimating the survival function 146
5.6 Additive rate models 149
5.7 Goodness-of-fit procedures 151
5.8 Example 159
5.9 Exercises 165

6 Multiplicative hazards models **175**
6.1 The Cox model 181
6.2 Goodness-of-fit procedures for the Cox model 193
6.3 Extended Cox model with time-varying regression effects . . 205
6.4 Inference for the extended Cox model 213
6.5 A semiparametric multiplicative hazards model 218
6.6 Inference for the semiparametric multiplicative model . . . 224
6.7 Estimating the survival function 226
6.8 Multiplicative rate models 227
6.9 Goodness-of-fit procedures 228
6.10 Examples 234
6.11 Exercises 240

7 Multiplicative-Additive hazards models **249**
7.1 The Cox-Aalen hazards model 251
7.1.1 Model and estimation 252
7.1.2 Inference and large sample properties 255
7.1.3 Goodness-of-fit procedures 260
7.1.4 Estimating the survival function 266
7.1.5 Example 270
7.2 Proportional excess hazards model 273
7.2.1 Model and score equations 274
7.2.2 Estimation and inference 276
7.2.3 Efficient estimation 280
7.2.4 Goodness-of-fit procedures 283
7.2.5 Examples 284
7.3 Exercises 290

8 Accelerated failure time and transformation models **293**
8.1 The accelerated failure time model 294
8.2 The semiparametric transformation model 298

8.3 Exercises 309

9 Clustered failure time data **313**
9.1 Marginal regression models for clustered failure time data . 314
9.1.1 Working independence assumption 315
9.1.2 Two-stage estimation of correlation 327
9.1.3 One-stage estimation of correlation 330
9.2 Frailty models 334
9.3 Exercises 338

10 Competing Risks Model **347**
10.1 Product limit estimator 351
10.2 Cause specific hazards modeling 356
10.3 Subdistribution approach 361
10.4 Exercises 370

11 Marked point process models **375**
11.1 Nonparametric additive model for longitudinal data 380
11.2 Semiparametric additive model for longitudinal data 389
11.3 Efficient estimation 393
11.4 Marginal models 397
11.5 Exercises 408

A Khmaladze's transformation **411**

B Matrix derivatives **415**

C The Timereg survival package for R **417**

Bibliography **453**

Index **467**