
Contents

| | |
|--|-----|
| Preface | VII |
| 1 Introduction and Examples | 1 |
| 1.1 Correlated Data | 1 |
| 1.2 Longitudinal Data Analysis | 2 |
| 1.3 Data Examples | 6 |
| 1.3.1 Indonesian Children's Health Study | 6 |
| 1.3.2 Epileptic Seizures Data | 7 |
| 1.3.3 Retinal Surgery Data | 9 |
| 1.3.4 Orientation of Sandhoppers | 10 |
| 1.3.5 Schizophrenia Clinical Trial | 11 |
| 1.3.6 Multiple Sclerosis Trial | 13 |
| 1.3.7 Tretinoin Emollient Cream Trial | 13 |
| 1.3.8 Polio Incidences in USA | 14 |
| 1.3.9 Tokyo Rainfall Data | 15 |
| 1.3.10 Prince George Air Pollution Study | 16 |
| 1.4 Remarks | 19 |
| 1.5 Outline of Subsequent Chapters | 20 |
| 2 Dispersion Models | 23 |
| 2.1 Introduction | 23 |
| 2.2 Dispersion Models | 25 |
| 2.2.1 Definitions | 26 |
| 2.2.2 Properties | 28 |
| 2.3 Exponential Dispersion Models | 30 |
| 2.4 Residuals | 35 |
| 2.5 Tweedie Class | 36 |
| 2.6 Maximum Likelihood Estimation | 37 |
| 2.6.1 General Theory | 38 |
| 2.6.2 MLE in the ED Models | 41 |
| 2.6.3 MLE in the Simplex GLM | 42 |

| | | |
|----------|---|-----------|
| 2.6.4 | MLE in the von Mises GLM | 49 |
| 3 | Inference Functions | 55 |
| 3.1 | Introduction | 55 |
| 3.2 | Quasi-Likelihood Inference in GLMs | 56 |
| 3.3 | Preliminaries..... | 58 |
| 3.4 | Optimal Inference Functions | 61 |
| 3.5 | Multi-Dimensional Inference Functions | 65 |
| 3.6 | Generalized Method of Moments | 68 |
| 4 | Modeling Correlated Data | 73 |
| 4.1 | Introduction | 73 |
| 4.2 | Quasi-Likelihood Approach | 76 |
| 4.3 | Conditional Modeling Approaches | 80 |
| 4.3.1 | Latent Variable Based Approach | 80 |
| 4.3.2 | Transitional Model Based Approach | 82 |
| 4.4 | Joint Modeling Approach..... | 84 |
| 5 | Marginal Generalized Linear Models | 87 |
| 5.1 | Model Formulation | 88 |
| 5.2 | GEE: Generalized Estimating Equations..... | 89 |
| 5.2.1 | General Theory | 90 |
| 5.2.2 | Some Special Cases | 93 |
| 5.2.3 | Wald Test for Nested Models | 95 |
| 5.3 | GEE2..... | 95 |
| 5.3.1 | Constant Dispersion Parameter | 96 |
| 5.3.2 | Varying Dispersion Parameter | 100 |
| 5.4 | Residual Analysis | 101 |
| 5.4.1 | Checking Distributional Assumption | 102 |
| 5.4.2 | Checking Constant Dispersion Assumption | 102 |
| 5.4.3 | Checking Link Functions | 102 |
| 5.4.4 | Checking Working Correlation | 102 |
| 5.5 | Quadratic Inference Functions..... | 103 |
| 5.6 | Implementation and Softwares | 106 |
| 5.6.1 | Newton-Scoring Algorithm | 106 |
| 5.6.2 | SAS PROC GENMOD | 107 |
| 5.6.3 | SAS MACRO QIF..... | 108 |
| 5.7 | Examples..... | 109 |
| 5.7.1 | Longitudinal Binary Data | 110 |
| 5.7.2 | Longitudinal Count Data..... | 112 |
| 5.7.3 | Longitudinal Proportional Data | 116 |

| | | |
|----------|---|-----|
| 6 | Vector Generalized Linear Models | 121 |
| 6.1 | Introduction | 121 |
| 6.2 | Log-Linear Model for Correlated Binary Data | 122 |
| 6.3 | Multivariate ED Family Distributions | 125 |
| 6.3.1 | Copulas | 126 |
| 6.3.2 | Construction | 127 |
| 6.3.3 | Interpretation of Association Parameter | 129 |
| 6.4 | Simultaneous Maximum Likelihood Inference | 136 |
| 6.4.1 | General Theory | 136 |
| 6.4.2 | VGLMs for Correlated Continuous Outcomes | 137 |
| 6.4.3 | VGLMs for Correlated Discrete Outcomes | 138 |
| 6.4.4 | Scores for Association Parameters | 139 |
| 6.5 | Algorithms | 141 |
| 6.5.1 | Algorithm I: Maximization by Parts | 142 |
| 6.5.2 | Algorithm II: Gauss-Newton Type | 146 |
| 6.6 | An Illustration: VGLMs for Trivariate Discrete Data | 146 |
| 6.6.1 | Trivariate VGLMs | 147 |
| 6.6.2 | Comparison of Asymptotic Efficiency | 148 |
| 6.7 | Data Examples | 150 |
| 6.7.1 | Analysis of Two-Period Cross-Over Trial Data | 150 |
| 6.7.2 | Analysis of Hospital Visit Data | 152 |
| 6.7.3 | Analysis of Burn Injury Data | 153 |
| 7 | Mixed-Effects Models: Likelihood-Based Inference | 157 |
| 7.1 | Introduction | 157 |
| 7.2 | Model Specification | 161 |
| 7.3 | Estimation | 165 |
| 7.4 | MLE Based on Numerical Integration | 167 |
| 7.5 | Simulated MLE | 175 |
| 7.6 | Conditional Likelihood Estimation | 176 |
| 7.7 | MLE Based on EM Algorithm | 178 |
| 7.8 | Approximate Inference: PQL and REML | 182 |
| 7.9 | SAS Software | 192 |
| 7.9.1 | PROC MIXED | 192 |
| 7.9.2 | PROC NLMIXED | 193 |
| 7.9.3 | PROC GLIMMIX | 194 |
| 8 | Mixed-Effects Models: Bayesian Inference | 195 |
| 8.1 | Bayesian Inference Using MCMC Algorithm | 195 |
| 8.1.1 | Gibbs Sampling: A Practical View | 195 |
| 8.1.2 | Diagnostics | 198 |
| 8.1.3 | Enhancing Burn-in | 201 |
| 8.1.4 | Model Selection | 202 |
| 8.2 | An Illustration: Multiple Sclerosis Trial Data | 203 |
| 8.3 | Multi-Level Correlated Data | 206 |

| | | |
|-----------|--|------------|
| 8.4 | WinBUGS Software | 212 |
| 8.4.1 | WinBUGS Code in Multiple Sclerosis Trial Data Analysis | 213 |
| 8.4.2 | WinBUGS Code for the TEC Drug Analysis | 214 |
| 9 | Linear Predictors | 217 |
| 9.1 | General Results | 217 |
| 9.2 | Estimation of Random Effects in GLMMs | 221 |
| 9.2.1 | Estimation in LMMs | 221 |
| 9.2.2 | Estimation in GLMMs | 221 |
| 9.3 | Kalman Filter and Smoother | 222 |
| 9.3.1 | General Forms | 222 |
| 10 | Generalized State Space Models | 227 |
| 10.1 | Introduction | 227 |
| 10.2 | Linear State Space Models | 231 |
| 10.3 | Shift-Mean Model | 232 |
| 10.4 | Monte Carlo Maximum Likelihood Estimation | 235 |
| 11 | Generalized State Space Models for Longitudinal Binomial Data | 239 |
| 11.1 | Introduction | 239 |
| 11.2 | Monte Carlo Kalman Filter and Smoother | 240 |
| 11.3 | Bayesian Inference Based on MCMC | 246 |
| 12 | Generalized State Space Models for Longitudinal Count Data | 261 |
| 12.1 | Introduction | 261 |
| 12.2 | Generalized Estimating Equation | 264 |
| 12.3 | Monte Carlo EM Algorithm | 265 |
| 12.4 | KEE in Stationary State Processes | 267 |
| 12.4.1 | Setup | 267 |
| 12.4.2 | Kalman Filter and Smoother | 269 |
| 12.4.3 | Godambe Information Matrix | 271 |
| 12.4.4 | Analysis of Polio Incidences Data | 272 |
| 12.5 | KEE in Non-Stationary State Processes | 275 |
| 12.5.1 | Model Formulation | 275 |
| 12.5.2 | Kalman Filter and Smoother | 278 |
| 12.5.3 | Parameter Estimation | 280 |
| 12.5.4 | Model Diagnosis | 281 |
| 12.5.5 | Analysis of Prince George Data | 283 |

13 Missing Data in Longitudinal Studies 291

13.1 Introduction 291

13.2 Missing Data Patterns 293

 13.2.1 Patterns of Missingness 293

 13.2.2 Types of Missingness and Effects 297

13.3 Diagnosis of Missing Data Types 300

 13.3.1 Graphic Approach 301

 13.3.2 Testing for MCAR..... 302

13.4 Handling MAR Mechanism 306

 13.4.1 Simple Solutions and Limitations..... 307

 13.4.2 Multiple Imputation 307

 13.4.3 EM Algorithm 311

 13.4.4 Inverse Probability Weighting 317

13.5 Handling NMAR Mechanism 320

 13.5.1 Parametric Modeling 320

 13.5.2 A Semiparametric Pattern Mixture Model 322

References 329

Index 343