Contents

1 User's Manual 1
- 1.1 Expectations 2
- 1.2 Prerequisites and Further Reading 3
- 1.3 Styles and Fonts 4
- 1.4 An Introduction to R 5
  - 1.4.1 Getting Started 6
  - 1.4.2 R Objects 8
  - 1.4.3 Probability Distributions in R 15
  - 1.4.4 Graphical Facilities 16
  - 1.4.5 Writing New R Functions 19
  - 1.4.6 Input and Output in R 21
  - 1.4.7 Administration of R Objects 21
- 1.5 The bayess Package 22

2 Normal Models 25
- 2.1 Normal Modeling 26
- 2.2 The Bayesian Toolkit 28
  - 2.2.1 Posterior Distribution 28
  - 2.2.2 Bayesian Estimates 33
  - 2.2.3 Conjugate Prior Distributions 34
  - 2.2.4 Noninformative Priors 35
  - 2.2.5 Bayesian Credible Intervals 37
- 2.3 Bayesian Model Choice 38
  - 2.3.1 The Model Index as a Parameter 39
  - 2.3.2 The Bayes Factor 41
  - 2.3.3 The Ban on Improper Priors 43
- 2.4 Monte Carlo Methods 46
  - 2.4.1 An Approximation Based on Simulations 47
  - 2.4.2 Importance Sampling 49
  - 2.4.3 Approximation of Bayes Factors 52

2.5 Outlier Detection 58
2.6 Exercises 61

3 Regression and Variable Selection 65
3.1 Linear Models 66
3.2 Classical Least Squares Estimator 69
3.3 The Jeffreys Prior Analysis 73
3.4 Zellner's G-Prior Analysis 74
3.4.1 A Semi-noninformative Solution 75
3.4.2 The BayesReg R Function 80
3.4.3 Bayes Factors and Model Comparison 81
3.4.4 Prediction 84
3.5 Markov Chain Monte Carlo Methods 85
3.5.1 Conditionals 86
3.5.2 Two-Stage Gibbs Sampler 87
3.5.3 The General Gibbs Sampler 90
3.6 Variable Selection 91
3.6.1 Deciding on Explanatory Variables 91
3.6.2 G-Prior Distributions for Model Choice 93
3.6.3 A Stochastic Search for the Most Likely Model 96
3.7 Exercises 98

4 Generalized Linear Models 103
4.1 A Generalization of the Linear Model 104
4.1.1 Motivation 104
4.1.2 Link Functions 106
4.2 Metropolis Hastings Algorithms 108
4.2.1 Definition 109
4.2.2 The Independence Sampler 110
4.2.3 The Random Walk Sampler 111
4.2.4 Output Analysis and Proposal Design 111
4.3 The Probit Model 115
4.3.1 Flat Prior 115
4.3.2 Noninformative G-Priors 117
4.3.3 About Informative Prior Analyses 122
4.4 The Logit Model 124
4.5 Log-Linear Models 127
4.5.1 Contingency Tables 127
4.5.2 Inference Under a Flat Prior 131
4.5.3 Model Choice and Significance of the Parameters 133
4.6 Exercises 137

5 Capture–Recapture Experiments 139
5.1 Inference in a Finite Population 140
5.2 Sampling Models 142
5.2.1 The Binomial Capture Model 142
5.2.2 The Two-Stage Capture–Recapture Model 143
5.2.3 The T-Stage Capture–Recapture Model 148
5.3 Open Populations 152
5.4 Accept–Reject Algorithms 156
5.5 The Arnason–Schwarz Capture–Recapture Model 160
5.5.1 Modeling 161
5.5.2 Gibbs Sampler 165
5.6 Exercises 168

6 Mixture Models 173
6.1 Missing Variable Models 174
6.2 Finite Mixture Models 176
6.3 Mixture Likelihoods and Posteriors 177
6.4 MCMC Solutions 182
6.5 Label Switching Difficulty 192
6.6 Prior Selection 198
6.7 Tempering 199
6.8 Mixtures with an Unknown Number of Components 201
6.9 Exercises 206

7 Time Series 209
7.1 Time-Indexed Data 210
7.1.1 Setting 210
7.1.2 Stability of Time Series 212
7.2 Autoregressive (AR) Models 214
7.2.1 The Models 215
7.2.2 Exploring the Parameter Space by MCMC Algorithms 219
7.3 Moving Average (MA) Models 226
7.4 ARMA Models and Other Extensions 232
7.5 Hidden Markov Models 236
7.5.1 Basics 237
7.5.2 Forward–Backward Representation 241
7.6 Exercises 248

8 Image Analysis 251
8.1 Image Analysis as a Statistical Problem 252
8.2 Spatial Dependence 252
8.2.1 Grids and Lattices 252
8.2.2 Markov Random Fields 254
8.2.3 The Ising Model 256
8.2.4 The Potts Model 260

8.3 Handling the Normalizing Constant 262
8.3.1 Path Sampling 264
8.3.2 The ABC Method 267
8.3.3 Inference on Potts Models 270
8.4 Image Segmentation 273
8.5 Exercises 281

About the Authors 285

References 287

Index 291