

Contents

Preface	xi
Acknowledgements	xiii
Chapter 1 Introduction: The Bayesian Method, its Benefits and Implementation	1
1.1 Advantages of the Bayes approach	1
1.2 Statements about uncertainty and Bayesian updating	2
1.2.1 Prior and likelihood	3
1.3 Using existing knowledge to specify priors	4
1.4 The Sampling perspective: estimating the densities of parameters	6
1.5 Predictions from sampling	7
1.6 The present book	8
Chapter 2 Standard Distributions: Updating, Inference and Prediction	11
2.1 Introduction	11
2.2 Continuous data models: univariate normal	12
2.2.1 Estimating a normal mean when the variance is known	12
2.2.2 Predictions and predictive distributions	13
2.2.3 Samples of $n > 1$ observations	14
2.2.4 Hypothesis tests	15
2.2.5 Interval and point hypotheses	16
2.2.6 Posterior predictive checks	17
2.3 Inference on normal parameters, mean and variance unknown	19
2.3.1 Normal distribution: mean and variance unknown and interdependent	22
2.3.2 Comparison of variances	23
2.3.3 Comparison of several means	24
2.4 The t density as a heavy-tailed alternative to the normal distribution	25
2.5 Categorical data models: binomial, Poisson and multinomial	27

2.5.1	Binomial outcomes	28
2.5.2	Using prior knowledge to estimate the beta prior	30
2.6	Poisson distribution for event counts	34
2.7	Polytomous outcomes via the multinomial density	37
2.8	Multivariate continuous data: MVN and multivariate t densities	41
2.8.1	Multivariate normal with unknown mean and variance	42
2.8.2	Hypotheses on multivariate means	52
2.9	Power and sample size calculations	53
2.9.1	Sample size specification to achieve a desired accuracy	53
2.9.2	Sample size specifications for testing hypotheses	55
	Notes	61
Chapter 3	Models for Association and Classification	63
3.1	Introduction: association and classification	63
3.2	Analysing association in observational studies: follow-up and case control studies	65
3.2.1	Simulating controls through historic exposure	69
3.2.2	Accounting for stratification in study design	71
3.3.3	Attributable risk: effects of eliminating postulated causes	73
3.4	Controlled experiments and trials	75
3.5	Classification, screening and diagnostic accuracy	80
3.5.1	Multivariate discrimination	86
Chapter 4	Normal Linear Regression, General Linear Models and Log-Linear Models	91
4.1	The context for Bayesian regression methods	91
4.2	The univariate linear regression model	94
4.2.1	Posterior for β , precision known	94
4.2.2	Posterior for β and τ , precision unknown	95
4.3	Multicollinearity and robust regression methods	99
4.4	Nonparametric regression via splines	105
4.5	General linear models: logit and Poisson regression	109
4.5.1	Poisson regression	118
4.5.2	General nonlinear models	121
4.6	General linear models for survey data	127
4.7	Log-linear models for crossed categorical outcomes	129
4.7.1	The two-way contingency table	130
4.7.2	Modelling choices and strategies	132

4.7.3	Fitting log-linear models for a two-way model	133
4.7.4	The quasi-symmetry model	136
4.8	Variable and model selection in regression and log-linear models	139
4.8.1	Selection among regression models	140
4.8.2	Selection of log-linear models	143
4.9	Log-linear models for cumulated event data	145
4.10	Markov chain models	149
4.11	Multivariate categorical outcomes	151
4.12	Ordered outcomes	154
4.12.1	Scores for ordered outcomes	157
Chapter 5	Ensemble Estimates: Hierarchical Priors for Pooling Strength	163
5.1	Hierarchical priors: improved precision through borrowing strength	163
5.1.1	Pooling strength: Poisson outcomes	165
5.1.2	Pooling strength: binomial outcomes	168
5.2	Overdispersed categorical data and random effects models	174
5.3	Models for polytomies and histograms: extra-variation in multinomial models	178
5.3.1	Histogram smoothing	180
5.4	League tables and meta-analyses	181
5.5	Meta-analysis	185
5.5.1	Combining over design types and selection bias	188
5.6	Estimating population parameters from survey data	190
5.6.1	Modelling missing cells in multi-way designs	194
5.6.2	Two-stage sampling for proportions	196
Chapter 6	Latent Variables, Mixture Analysis and Models for NonResponse	199
6.1	Introduction	199
6.1.1	Missing data models	200
6.1.2	Latent traits vs latent classes	200
6.1.3	Regression and transition mixtures	202
6.1.4	Latent factor models, latent class analysis and item analysis	202
6.1.5	Item analysis	205
6.1.6	Polytomous outcomes	207
6.1.7	Latent class analysis (LCA)	209
6.1.8	Multiple categorical outcomes	213
6.2	Mixtures of distributions, regression mixtures and transition mixtures	214
6.2.1	BUGS implementation	216

6.2.2	Normal mixtures	220
6.3	Latent transition matrices and mixtures of transition matrices	223
6.4	Models for nonresponse and incomplete data	230
6.5	Missingness patterns: factored likelihoods for multivariate missing data	233
6.5.1	Multiple imputation	236
6.6	Ignorable and non-ignorable missingness: estimating missing counts in contingency tables	239
6.6.1	Hierarchical models for non-ignorable nonresponse	241
6.6.2	Parameterisation of differential nonresponse	243
6.6.3	Polytomous and multivariate nonresponse patterns	251
6.6.4	Mixtures of continuous and categorical data	257
6.7	Nonparametric mixture modelling via Dirichlet process priors	260
6.7.1	Data smoothing	266
6.7.2	Other nonparametric priors	267
Chapter 7	Correlated Data Models	275
7.1	Introduction	275
7.1.1	Time series analysis	275
7.1.2	Spatial modelling	277
7.1.3	Contemporaneous correlation in systems of equations and in measurement error models	279
7.2	Temporal correlation described by autoregressive processes	281
7.2.1	Priors on autoregressive coefficients	282
7.2.2	Stationarity priors in the $AR(p)$ model	283
7.2.3	Initial conditions as latent data	284
7.2.4	Predictions	285
7.3	Autoregressive moving average models	287
7.3.1	Initial conditions in the ARMA model	289
7.3.2	Normality assumptions	290
7.4	Outlier and intervention models	295
7.5	Regression with autocorrelated errors in time	297
7.5.1	Cointegration and unit root testing	303
7.6	Linear dynamic models and time varying coefficients	305
7.6.1	The general DLM framework	307
7.6.2	On-line vs retrospective analysis	308
7.6.3	Random walk and other autoregressive priors	309
7.6.4	Discounted priors for time-specific variances	310
7.6.5	Priors under interventions	311

7.7	Spectral time series analysis	322
7.8	Time series formulations of nonparametric regression	327
7.8.1	Continuous time prior	327
7.8.2	Fourier series prior	329
7.8.3	Discrete time priors	329
7.8.4	Implementation of time series priors	330
7.9	Spatial correlation	335
7.9.1	Hypothesis tests	336
7.9.2	Regression models for area outcomes	336
7.10	Continuous spatial processes	340
7.11	Measurement error, seemingly unrelated Regressions, and simultaneous equations	346
7.11.1	Double regressions	350
7.11.2	Epidemiological applications	353
7.12	Sets of relationships	356
7.13	Simultaneous equations	358
7.13.1	Using instruments: two-and three-stage least squares	360
7.13.2	The consumption model	361
	Notes	365

Chapter 8	Multilevel Models, Multivariate Analysis and Longitudinal Models	367
8.1	Introduction	367
8.1.1	Multivariate robustness and identification	369
8.1.2	Ecological and atomistic fallacies	370
8.2	General linear multilevel models for hierarchical data sets	371
8.3	Panel data models and growth curves	375
8.3.1	Marginal and transition models	375
8.3.2	Random effects models	376
8.3.3	Autocorrelation in errors	378
8.4	Dynamic models for longitudinal and growth curve data	384
8.4.1	Growth curve models as DLMS	387
8.5	Multivariate regression, factor analysis and structural equation models	390
8.5.1	Multivariate regression for imputation of missing data	393
8.6	Factor analysis and structural equation models	394
8.6.1	Stochastic volatility by factor analysis	401
8.6.2	Structural equation modelling (SEM)	403
8.6.3	Different group means and covariances on latent variables	407
8.7	Multivariate hierarchical models	411

8.8	Small area and survey domain estimation	415
8.8.1	Modelling small area rates	416
Chapter 9	Life Table and Survival Analysis	423
9.1	Introduction	423
9.2	Survival analysis in continuous time: parametric modelling of duration and covariates	425
9.2.1	Modelling covariate impacts and time dependence in the hazard rate	427
9.2.2	Censored time observations	428
9.2.3	Survival analysis in BUGS	428
9.3	Non-monotonic hazards	432
9.4	Analysing competing risks in continuous time	433
9.5	Variations in proneness: models for frailty	438
9.6	Counting process models	443
9.7	Discrete time survival models and life tables in discrete time	449
9.7.1	Discrete time event history models	449
9.8	Life tables: demographic and medical applications	451
9.8.1	Clinical and epidemiological applications	451
9.9	Population life tables	456
9.10	Competing risks population life tables	459
Chapter 10	Bayesian Estimation and Model Assessment	465
10.1	Introduction	465
10.2	Model comparison and fit	469
10.3	Separate model estimation	472
10.3.1	Overall fit measures	472
10.3.2	Predictive fit measures	477
10.3.3	Posterior likelihood comparison methods	479
10.4	Simultaneous model assessment	480
	Appendix	493
	References	495
	Index	515