

Contents

Preface (Second Edition)	vii
Preface (First Edition)	xi
1 Hello World: Introducing Spatial Data	1
1.1 Applied Spatial Data Analysis	1
1.2 Why Do We Use R	2
1.2.1 ... In General?	2
1.2.2 ...for Spatial Data Analysis?	3
1.2.3 ...and for Reproducible Research?	4
1.3 R and GIS	5
1.3.1 What Is GIS?	5
1.3.2 Service-Oriented Architectures	6
1.3.3 Further Reading on GIS	6
1.4 Types of Spatial Data	8
1.5 Storage and Display	10
1.6 Applied Spatial Data Analysis	11
1.7 R Spatial Resources	14
1.8 Layout of the Book	15
Part I Handling Spatial Data in R	
2 Classes for Spatial Data in R	21
2.1 Introduction	21
2.2 Classes and Methods in R	23
2.3 Spatial Objects	28
2.4 SpatialPoints	30
2.4.1 Methods	31
2.4.2 Data Frames for Spatial Point Data	33

2.5	SpatialLines	37
2.6	SpatialPolygons	41
	2.6.1 SpatialPolygonsDataFrame Objects	44
	2.6.2 Holes and Ring Direction	46
2.7	SpatialGrid and SpatialPixel Objects	48
2.8	Raster Objects and the raster Package	54
3	Visualising Spatial Data	59
3.1	The Traditional Plot System	60
	3.1.1 Plotting Points, Lines, Polygons, and Grids	60
	3.1.2 Axes and Layout Elements	61
	3.1.3 Degrees in Axes Labels and Reference Grid	65
	3.1.4 Plot Size, Plotting Area, Map Scale, and Multiple Plots	66
	3.1.5 Plotting Attributes and Map Legends	68
3.2	Trellis/Lattice Plots with spplot	69
	3.2.1 A Straight Trellis Example	70
	3.2.2 Plotting Points, Lines, Polygons, and Grids	70
	3.2.3 Adding Reference and Layout Elements to Plots	73
	3.2.4 Arranging Panel Layout	74
3.3	Alternatives Routes: ggplot , latticeExtra	75
3.4	Interactive Plots	76
	3.4.1 Interacting with Base Graphics	77
	3.4.2 Interacting with spplot and Lattice Plots	78
3.5	Colour Palettes and Class Intervals	79
	3.5.1 Colour Palettes	79
	3.5.2 Class Intervals	79
4	Spatial Data Import and Export	83
4.1	Coordinate Reference Systems	84
	4.1.1 Using the EPSG List	85
	4.1.2 PROJ.4 CRS Specification	86
	4.1.3 Projection and Transformation	88
	4.1.4 Degrees, Minutes, and Seconds	90
4.2	Vector File Formats	91
	4.2.1 Using OGR Drivers in rgdal	92
	4.2.2 Other Import/Export Functions	99
4.3	Raster File Formats	100
	4.3.1 Using GDAL Drivers in rgdal	100
	4.3.2 Other Import/Export Functions	107
4.4	Google Earth™, Google Maps™ and Other Formats	108
4.5	Geographical Resources Analysis Support System (GRASS) ..	112
	4.5.1 Broad Street Cholera Data	118
4.6	Other Import/Export Interfaces	122
	4.6.1 Analysis and Visualisation Applications	122

4.6.2	TerraLib and aRT	123
4.6.3	Other GIS Systems	124
4.7	Installing rgdal	125
5	Further Methods for Handling Spatial Data	127
5.1	Support	127
5.2	Handling and Combining Features	130
5.2.1	The rgeos Package	130
5.2.2	Using rgeos	132
5.3	Map Overlay or Spatial Join	140
5.3.1	Spatial Aggregation	142
5.3.2	Using the raster Package for Extract Operations	145
5.3.3	Spatial Sampling	146
5.4	Auxiliary Functions	149
6	Spatio-Temporal Data	151
6.1	Introduction	151
6.2	Types of Spatio-Temporal Data	151
6.2.1	Spatial Point or Area, Time Instance or Interval	152
6.2.2	Are Space and Time of <i>Primary</i> Interest?	152
6.2.3	Regularity of Space-Time Layouts	152
6.2.4	Do Objects Change Location?	153
6.3	Classes in spacetime	154
6.4	Handling Time Series Data with xts	155
6.5	Construction of ST Objects	156
6.6	Selection, Addition, and Replacement of Attributes	158
6.7	Overlay and Aggregation	159
6.8	Visualisation	161
6.8.1	Multi-panel Plots	161
6.8.2	Space-Time Plots	162
6.8.3	Animated Plots	163
6.8.4	Time Series Plots	164
6.9	Further Packages	164
6.9.1	Handling Spatio-Temporal Data	165
6.9.2	Analysing Spatio-Temporal Data	165
6.10	Outlook	165

Part II Analysing Spatial Data

7	Spatial Point Pattern Analysis	173
7.1	Introduction	173
7.2	Packages for the Analysis of Spatial Point Patterns	174
7.3	Preliminary Analysis of a Point Pattern	178
7.3.1	Complete Spatial Randomness	179
7.3.2	<i>G</i> Function: Distance to the Nearest Event	179

7.3.3	<i>F</i> Function: Distance from a Point to the Nearest Event	181
7.4	Statistical Analysis of Spatial Point Processes	182
7.4.1	Homogeneous Poisson Processes	183
7.4.2	Inhomogeneous Poisson Processes	184
7.4.3	Estimation of the Intensity	184
7.4.4	Likelihood of an Inhomogeneous Poisson Process	187
7.4.5	Second-Order Properties	190
7.5	Some Applications in Spatial Epidemiology	192
7.5.1	Case–Control Studies	193
7.5.2	Binary Regression Estimator	198
7.5.3	Binary Regression Using Generalised Additive Models	199
7.5.4	Point Source Pollution	202
7.5.5	Accounting for Confounding and Covariates	206
7.6	Further Methods for the Analysis of Point Patterns	210
8	Interpolation and Geostatistics	213
8.1	Introduction	213
8.2	Exploratory Data Analysis	214
8.3	Non-geostatistical Interpolation Methods	215
8.3.1	Inverse Distance Weighted Interpolation	215
8.3.2	Linear Regression	216
8.4	Estimating Spatial Correlation: The Variogram	217
8.4.1	Exploratory Variogram Analysis	219
8.4.2	Cutoff, Lag Width, Direction Dependence	222
8.4.3	Variogram Modelling	224
8.4.4	Anisotropy	228
8.4.5	Multivariable Variogram Modelling	229
8.4.6	Residual Variogram Modelling	230
8.5	Spatial Prediction	232
8.5.1	Universal, Ordinary, and Simple Kriging	233
8.5.2	Multivariable Prediction: Cokriging	233
8.5.3	Collocated Cokriging	236
8.5.4	Cokriging Contrasts	237
8.5.5	Kriging in a Local Neighbourhood	237
8.5.6	Change of Support: Block Kriging	238
8.5.7	Stratifying the Domain	240
8.5.8	Trend Functions and Their Coefficients	241
8.5.9	Non-linear Transforms of the Response Variable	242
8.5.10	Singular Matrix Errors	243
8.6	Kriging, Filtering, Smoothing	245
8.7	Model Diagnostics	247
8.7.1	Cross Validation Residuals	247
8.7.2	Cross Validation <i>z</i> -Scores	249

8.7.3	Multivariable Cross Validation	250
8.7.4	Limitations to Cross Validation	250
8.8	Geostatistical Simulation	252
8.8.1	Sequential Simulation	252
8.8.2	Non-linear Spatial Aggregation and Block Averages ...	254
8.8.3	Multivariable and Indicator Simulation	255
8.9	Model-Based Geostatistics and Bayesian Approaches	256
8.10	Monitoring Network Optimisation	256
8.11	Other R Packages for Interpolation and Geostatistics	258
8.11.1	Non-geostatistical Interpolation	258
8.11.2	Spatial	259
8.11.3	RandomFields	259
8.11.4	geoR and geoRglm	259
8.11.5	Fields	260
8.11.6	spBayes	260
8.12	Spatio-Temporal Prediction	260
9	Modelling Areal Data	263
9.1	Introduction	263
9.2	Spatial Neighbours and Spatial Weights	266
9.2.1	Neighbour Objects	266
9.2.2	Spatial Weights Objects	269
9.2.3	Handling Spatial Weights Objects	273
9.2.4	Using Weights to Simulate Spatial Autocorrelation ...	274
9.3	Testing for Spatial Autocorrelation	275
9.3.1	Global Tests	278
9.3.2	Local Tests	284
9.4	Fitting Models of Areal Data	288
9.4.1	Spatial Statistics Approaches	290
9.4.2	Spatial Econometrics Approaches	303
9.4.3	Other Methods	314
10	Disease Mapping	319
10.1	Introduction	320
10.2	Statistical Models	322
10.2.1	Poisson-Gamma Model	323
10.2.2	Log-Normal Model	325
10.2.3	Marshall's Global EB Estimator	326
10.3	Spatially Structured Statistical Models	328
10.4	Bayesian Hierarchical Models	330
10.4.1	The Poisson-Gamma Model Revisited	332
10.4.2	Spatial Models	336
10.5	Geoadditive Models	345
10.6	Detection of Clusters of Disease	347
10.6.1	Testing the Homogeneity of the Relative Risks	348
10.6.2	Moran's <i>I</i> Test of Spatial Autocorrelation	350
10.6.3	Tango's Test of General Clustering	351

10.6.4	Detection of the Location of a Cluster	352
10.6.5	Geographical Analysis Machine	353
10.6.6	Kulldorff's Statistic	353
10.6.7	Stone's Test for Localised Clusters.....	355
10.7	Spatio-Temporal Disease Mapping	356
10.7.1	Introduction	356
10.7.2	Spatio-Temporal Modelling of Disease.....	357
10.8	Other Topics in Disease Mapping	361
Afterword		363
	R and Package Versions Used	364
	Data Sets Used	364
References		367
Subject Index		387
Functions Index		401