

QUANTITATIVE GEOGRAPHY

**Perspectives on
Spatial Data Analysis**

- **A. Stewart Fotheringham**
- **Chris Brunsdon**
- **Martin Charlton**

SAGE Publications
London • Thousand Oaks • New Delhi

Contents

Preface	xi
1 Establishing the Boundaries	1
1.1 Setting the scene	1
1.2 What is quantitative geography?	4
1.3 Applications of quantitative geography	8
1.4 Recent developments in quantitative geography	10
1.5 Summary	13
Notes	14
2 Spatial Data	15
2.1 Introduction	15
2.2 Spatial data capture	16
2.3 Spatial objects	17
2.4 Location on the globe; location on a plane	18
2.5 Distance	20
2.6 Representing spatial data	21
2.7 Models for spatial data	22
2.7.1 The vector model	22
2.7.2 The raster model	23
2.8 Programming with spatial data	24
2.8.1 Point-in-polygon operations	24
2.8.2 The use of complex numbers to represent spatial data	25
2.9 Problems and opportunities	25
2.10 Summary	29
Notes	29
3 The Role of Geographical Information Systems	80
3.1 Introduction	30
3.2 Simple GIS-based spatial analysis	32
3.2.1 Feature selection by attribute	32
3.2.2 Feature selection by geometric intersection	33
3.2.3 Buffering features	34
3.2.4 Geometric intersection: union	35
3.2.5 Geometric intersection: intersection	37
3.2.6 Proximity	38
3.2.7 Contiguity	41

3.2.8	Interpolation and fields	42
3.2.9	Density functions	45
3.2.10	Analysis on networks	46
3.2.11	Query	49
3.3	Advanced GIS-based spatial analysis	49
3.3.1	Data-integration and management	51
3.3.2	Exploration	54
3.3.3	Post-modelling visualization	55
3.4	Problems	58
3.4.1	Error modelling	58
3.4.2	Cross-area aggregation	59
3.5	Linking higher-order types of spatial analysis to GIS	61
3.6	A role for GIS?	64
	Notes	64
4	Exploring Spatial Data Visually	65
4.1	Introduction	65
4.2	Stem and leaf plots	66
4.3	Boxplots	68
4.4	Histograms	70
4.5	Density estimates	71
4.6	Maps	72
4.7	The scatterplot matrix	75
4.8	Linked plots	77
4.9	Parallel coordinate plots	80
4.10	RADVIZ	82
4.11	Projection pursuit	86
4.12	Summary	91
	Notes	92
5	Local Analysis	93
5.1	Introduction	93
5.2	The nature of local variations in relationships	94
5.3	Measuring local relationships in univariate data	96
5.3.1	Local point pattern analysis	96
5.3.2	Other local measures of univariate spatial relationships	97
5.4	Measuring local relationships in multivariate data	102
5.4.1	Multilevel modelling	103
5.4.2	The spatial expansion method	106
5.4.3	Geographically weighted regression	107
5.5	An empirical comparison of the spatial expansion method and GWR	114
5.5.1	The data	114
5.5.2	Global regression model results	115
5.5.3	Spatial expansion method results	117
5.5.4	GWR results	118
5.6	Measuring local relationships in spatial interaction models	128
5.7	Summary	129
	Notes	129

Point Pattern Analysis	130
6.1 Introduction	130
6.2 Initial exploration	132
6.2.1 Scatterplots	132
6.2.2 Other exploratory plots	134
6.2.3 Non-graphical approaches to point pattern exploration	136
6.3 Modelling point patterns	138
6.4 First-order intensity analysis	144
6.4.1 Kernel density estimates	146
6.5 Second-order intensity analysis	149
6.6 Comparing distributions	154
6.6.1 Comparing kernel densities	155
6.6.2 Comparing AT functions	157
6.6.3 Comparing a point pattern with a 'population at risk'	159
6.7 Conclusions	160
Notes	161
 7 Spatial Regression and Geostatistical Models	 162
7.1 Introduction	162
7.2 Autoregressive models	166
7.2.1 Spatially autoregressive models	167
7.2.2 Spatial moving average models	169
7.3 Kriging	171
7.3.1 The statistical technique	171
7.3.2 A worked example	175
7.3.3 Trend surfaces from kriging residuals	176
7.4 Semi-parametric smoothing approaches	178
7.5 Conclusions	182
 8 Statistical Inference for Spatial Data	 184
8.1 Introduction	184
8.2 Informal inference	185
8.2.1 Exploratory data analysis (EDA) and visualization	185
8.2.2 Data mining	187
8.2.2.1 Cluster analysis	188
8.2.2.2 Neural networks	190
8.3 Formal inference	193
8.3.1 Bayesian inference	193
8.3.2 Classical inference	198
8.3.3 Experimental and computational inference	201
8.3.3.1 Classical statistical inference and spatial autocorrelation	201
8.3.3.2 Experimental distributions and spatial autocorrelation	204
8.3.3.3 An empirical comparison of classical and experimental inference	206
8.3.4 Model building and model testing	210
8.4 Conclusions	211
Notes	211

9	Spatial Modelling and the Evolution of <i>Spatial</i> Theory	213
9.1	Introduction	213
9.2	Spatial interaction as social physics (1860-1970)	215
9.3	Spatial interaction as statistical mechanics (1970-80)	217
9.4	Spatial interaction as aspatial information processing (1980-90)	222
9.5	Spatial interaction as spatial information processing (1990 onwards)	225
9.6	Summary	234
	Notes	235
10	Challenges in Spatial Data Analysis	236
10.1	Retrospect	236
10.2	Current challenges	237
10.2.1	The modifiable areal unit problem	237
10.2.2	Spatial non-stationarity	240
10.2.3	Alternative inferential frameworks (Bayes, MCMC)	242
10.2.4	Geometry	243
10.2.5	Basic spatial concepts: proximity and accessibility	244
10.2.6	Merging space and time	245
10.3	Training people to think spatially	246
10.3.1	Teaching quantitative geography	246
10.3.2	Software	247
10.4	Summary	247
	Bibliography	249
	Index	267