

Contents

Preface	xi
1 Introduction	1
1.1 Why geostatistics?	1
1.1.1 Generalizing	2
1.1.2 Description	5
1.1.3 Interpretation	5
1.1.4 Control	5
1.2 A little history	6
1.3 Finding your way	8
2 Basic Statistics	11
2.1 Measurement and summary	11
2.1.1 Notation	12
2.1.2 Representing variation	13
2.1.3 The centre	15
2.1.4 Dispersion	16
2.2 The normal distribution	18
2.3 Covariance and correlation	19
2.4 Transformations	20
2.4.1 Logarithmic transformation	21
2.4.2 Square root transformation	21
2.4.3 Angular transformation	22
2.4.4 Logit transformation	22
2.5 Exploratory data analysis and display	22
2.5.1 Spatial aspects	25
2.6 Sampling and estimation	26
2.6.1 Target population and units	28
2.6.2 Simple random sampling	28
2.6.3 Confidence limits	29
2.6.4 Student's t	30
2.6.5 The χ^2 distribution	31
2.6.6 Central limit theorem	32
2.6.7 Increasing precision and efficiency	32
2.6.8 Soil classification	35

3 Prediction and Interpolation	37
3.1 Spatial interpolation	37
3.1.1 Thiessen polygons (Voronoi polygons, Dirichlet tessellation)	38
3.1.2 Triangulation	38
3.1.3 Natural neighbour interpolation	39
3.1.4 Inverse functions of distance	40
3.1.5 Trend surfaces	40
3.1.6 Splines	42
3.2 Spatial classification and predicting from soil maps	42
3.2.1 Theory	43
3.2.2 Summary	45
4 Characterizing Spatial Processes: The Covariance and Variogram	47
4.1 Introduction	47
4.2 A stochastic approach to spatial variation: the theory of regionalized variables	48
4.2.1 Random variables	48
4.2.2 Random functions	49
4.3 Spatial covariance	50
4.3.1 Stationarity	52
4.3.2 Ergodicity	53
4.4 The covariance function	53
4.5 Intrinsic variation and the variogram	54
4.5.1 Equivalence with covariance	54
4.5.2 Quasi-stationarity	55
4.6 Characteristics of the spatial correlation functions	55
4.7 Which variogram?	60
4.8 Support and Krige's relation	60
4.8.1 Regularization	63
4.9 Estimating semivariances and covariances	65
4.9.1 The variogram cloud	65
4.9.2 h-Scattergrams	66
4.9.3 Average semivariances	67
4.9.4 The experimental covariance function	73
5 Modelling the Variogram	77
5.1 Limitations on variogram functions	79
5.1.1 Mathematical constraints	79
5.1.2 Behaviour near the origin	80
5.1.3 Behaviour towards infinity	82
5.2 Authorized models	82
5.2.1 Unbounded random variation	83
5.2.2 Bounded models	84

5.3	Combining models	95
5.4	Periodicity	97
5.5	Anisotropy	99
5.6	Fitting models	101
5.6.1	What weights?	104
5.6.2	How complex?	105
 6 Reliability of the Experimental Variogram and Nested Sampling		 109
6.1	Reliability of the experimental variogram	109
6.1.1	Statistical distribution	109
6.1.2	Sample size and design	119
6.1.3	Sample spacing	126
6.2	Theory of nested sampling and analysis	127
6.2.1	Link with regionalized variable theory	128
6.2.2	Case study: Youden and Mehlich's survey	129
6.2.3	Unequal sampling	131
6.2.4	Case study: Wyre Forest survey	134
6.2.5	Summary	138
 7 Spectral Analysis		 139
7.1	Linear sequences	139
7.2	Gilgai transect	140
7.3	Power spectra	142
7.3.1	Estimating the spectrum	144
7.3.2	Smoothing characteristics of windows	148
7.3.3	Confidence	149
7.4	Spectral analysis of the Caragabal transect	150
7.4.1	Bandwidths and confidence intervals for Caragabal	150
7.5	Further reading on spectral analysis	152
 8 Local Estimation or Prediction: Kriging		 153
8.1	General characteristics of kriging	154
8.1.1	Kinds of kriging	154
8.2	Theory of ordinary kriging	155
8.3	Weights	159
8.4	Examples	160
8.4.1	Kriging at the centre of the lattice	161
8.4.2	Kriging off-centre in the lattice and at a sampling point	169
8.4.3	Kriging from irregularly spaced data	172
8.5	Neighbourhood	172
8.6	Ordinary kriging for mapping	174

8.7	Case study	175
8.7.1	Kriging with known measurement error	180
8.7.2	Summary	180
8.8	Regional estimation	181
8.9	Simple kriging	183
8.10	Lognormal kriging	185
8.11	Optimal sampling for mapping	186
8.11.1	Isotropic variation	188
8.11.2	Anisotropic variation	190
8.12	Cross-validation	191
8.12.1	Scatter and regression	193
9	Kriging in the Presence of Trend and Factorial Kriging	195
9.1	Non-stationarity in the mean	195
9.1.1	Some background	196
9.2	Application of residual maximum likelihood	200
9.2.1	Estimation of the variogram by REML	200
9.2.2	Practicalities	203
9.2.3	Kriging with external drift	203
9.3	Case study	205
9.4	Factorial kriging analysis	212
9.4.1	Nested variation	212
9.4.2	Theory	212
9.4.3	Kriging analysis	213
9.4.4	Illustration	218
10	Cross-Correlation, Coregionalization and Cokriging	219
10.1	Introduction	219
10.2	Estimating and modelling the cross-correlation	222
10.2.1	Intrinsic coregionalization	224
10.3	Example: CEDAR Farm	226
10.4	Cokriging	228
10.4.1	Is cokriging worth the trouble?	231
10.4.2	Example of benefits of cokriging	232
10.5	Principal components of coregionalization matrices	235
10.6	Pseudo-cross-variogram	241
11	Disjunctive Kriging	243
11.1	Introduction	243
11.2	The indicator approach	246
11.2.1	Indicator coding	246
11.2.2	Indicator variograms	247
11.3	Indicator kriging	249

11.4 Disjunctive kriging	251
11.4.1 Assumptions of Gaussian disjunctive kriging	251
11.4.2 Hermite polynomials	252
11.4.3 Disjunctive kriging for a Hermite polynomial	254
11.4.4 Estimation variance	256
11.4.5 Conditional probability	256
11.4.6 Change of support	257
11.5 Case study	257
11.6 Other case studies	263
11.7 Summary	266

12 Stochastic Simulation **267**

12.1 Introduction	267
12.2 Simulation from a random process	268
12.2.1 Unconditional simulation	270
12.2.2 Conditional simulation	270
12.3 Technicalities	271
12.3.1 Lower–upper decomposition	272
12.3.2 Sequential Gaussian simulation	273
12.3.3 Simulated annealing	274
12.3.4 Simulation by turning bands	276
12.3.5 Algorithms	277
12.4 Uses of simulated fields	277
12.5 Illustration	278

Appendix A Aide-mémoire for Spatial Analysis **285**

A.1 Introduction	285
A.2 Notation	285
A.3 Screening	285
A.4 Histogram and summary	286
A.5 Normality and transformation	287
A.6 Spatial distribution	288
A.7 Spatial analysis: the variogram	288
A.8 Modelling the variogram	290
A.9 Spatial estimation or prediction: kriging	291
A.10 Mapping	292

Appendix B GenStat Instructions for Analysis **293**

B.1 Summary statistics	293
B.2 Histogram	294
B.3 Cumulative distribution	294
B.4 Posting	295
B.5 The variogram	295

x	Contents	
	B.5.1 Experimental variogram	295
	B.5.2 Fitting a model	296
B.6	Kriging	297
B.7	Coregionalization	297
	B.7.1 Auto- and cross-variograms	297
	B.7.2 Fitting a model of coregionalization	298
	B.7.3 Cokriging	298
B.8	Control	298
	References	299
	Index	309