

Contents

1	Introduction	1
1.1	Motivation for SDM	1
1.1.1	Superfluous Spatial Data	2
1.1.2	Hazards from Spatial Data	4
1.1.3	Attempts to Utilize Data	6
1.1.4	Proposal of SDM	8
1.2	The State of the Art of SDM	9
1.2.1	Academic Activities	9
1.2.2	Theoretical Techniques	10
1.2.3	Applicable Fields	11
1.3	Bottleneck of SDM	13
1.3.1	Excessive Spatial Data	13
1.3.2	High-Dimensional Spatial Data	13
1.3.3	Polluted Spatial Data	14
1.3.4	Uncertain Spatial Data	16
1.3.5	Mining Differences	17
1.3.6	Problems to Represent the Discovered Knowledge	17
1.3.7	Monograph Contents and Structures	18
1.4	Benefits to a Reader	20
	References	20
2	SDM Principles	23
2.1	SDM Concepts	23
2.1.1	SDM Characteristics	23
2.1.2	Understanding SDM from Different Views	25
2.1.3	Distinguishing SDM from Related Subjects	26
2.1.4	SDM Pyramid	27
2.1.5	Web SDM	29
2.2	From Spatial Data to Spatial Knowledge	30
2.2.1	Spatial Numerical	30
2.2.2	Spatial Data	31
2.2.3	Spatial Concept	31

2.2.4	Spatial Information.....	32
2.2.5	Spatial Knowledge.....	33
2.2.6	Unified Action.....	34
2.3	SDM Space.....	35
2.3.1	Attribute Space.....	35
2.3.2	Feature Space.....	35
2.3.3	Conceptual Space.....	36
2.3.4	Discovery State Space.....	36
2.4	SDM View.....	38
2.4.1	SDM User.....	38
2.4.2	SDM Method.....	39
2.4.3	SDM Application.....	39
2.4.4	SDM Hierarchy.....	40
2.4.5	SDM Granularity.....	42
2.4.6	SDM Scale.....	43
2.4.7	Discovery Mechanism.....	43
2.5	Spatial Knowledge to Discover.....	45
2.5.1	General Geometric Rule and Spatial Association Rule....	45
2.5.2	Spatial Characteristics Rule and Discriminate Rule....	48
2.5.3	Spatial Clustering Rule and Classification Rule.....	48
2.5.4	Spatial Predictable Rule and Serial Rule.....	49
2.5.5	Spatial Exception or Outlier.....	50
2.6	Spatial Knowledge Representation.....	51
2.6.1	Natural Language.....	51
2.6.2	Conversion Between Quantitative Data and Qualitative Concept.....	52
2.6.3	Spatial Knowledge Measurement.....	53
2.6.4	Spatial Rules Plus Exceptions.....	54
	References.....	55
3	SDM Data Source.....	57
3.1	Contents and Characteristics of Spatial Data.....	57
3.1.1	Spatial Objects.....	57
3.1.2	Contents of Spatial Data.....	58
3.1.3	Characteristics of Spatial Data.....	60
3.1.4	Diversity of Spatial Data.....	61
3.1.5	Spatial Data Fusion.....	62
3.1.6	Seamless Organization of Spatial Data.....	64
3.2	Spatial Data Acquisition.....	65
3.2.1	Point Acquisition.....	66
3.2.2	Area Acquisition.....	67
3.2.3	Mobility Acquisition.....	69
3.3	Spatial Data Formats.....	71
3.3.1	Vector Data.....	72
3.3.2	Raster Data.....	72
3.3.3	Vector-Raster Data.....	72

3.4	Spatial Data Model	75
3.4.1	Hierarchical Model and Network Model	76
3.4.2	Relational Model	76
3.4.3	Object-Oriented Model	78
3.5	Spatial Databases	81
3.5.1	Surveying and Mapping Database	81
3.5.2	DEM Database with Hierarchy	83
3.5.3	Image Pyramid	84
3.6	Spatial Data Warehouse	86
3.6.1	Data Warehouse	87
3.6.2	Spatial Data Cubes	87
3.6.3	Spatial Data Warehouse for Data Mining	89
3.7	National Spatial Data Infrastructure	90
3.7.1	American National Spatial Data Infrastructure	90
3.7.2	Geospatial Data System of Great Britain Ordnance Survey	96
3.7.3	German Authoritative Topographic-Cartographic Information System	96
3.7.4	Canadian National Topographic Data Base (NTDB)	97
3.7.5	Australian Land and Geographic Information System	98
3.7.6	Japanese Geographic Information System	98
3.7.7	Asia-Pacific Spatial Data Infrastructure	99
3.7.8	European Spatial Data Infrastructure	100
3.8	China's National Spatial Data Infrastructure	102
3.8.1	CNSDI Necessity and Possibility	102
3.8.2	CNSDI Contents	102
3.8.3	CNGDF of CNSDI	104
3.8.4	CSCTS of CNSDI	105
3.9	From GGDI to Big Data	107
3.9.1	GGDI	107
3.9.2	Digital Earth	109
3.9.3	Smart Planet	110
3.9.4	Big Data	111
3.10	Spatial Data as a Service	113
	References	117
4	Spatial Data Cleaning	119
4.1	Problems in Spatial Data	119
4.1.1	Polluted Spatial Data	120
4.1.2	Observation Errors in Spatial Data	123
4.1.3	Model Errors on Spatial Data	126
4.2	The State of the Art	129
4.2.1	Stages of Spatial Data Error Processing	129
4.2.2	The Underdevelopment of Spatial Data Cleaning	131

4.3	Characteristics and Contents of Spatial Data Cleaning	133
4.3.1	Fundamental Characteristics	133
4.3.2	Essential Contents	133
4.4	Systematic Error Cleaning	134
4.4.1	Direct Compensation Method	135
4.4.2	Indirect Compensation Method	136
4.5	Stochastic Error Cleaning	137
4.5.1	Function Model	137
4.5.2	Random Model	137
4.5.3	Estimation Equation	138
4.5.4	Various Special Circumstances	139
4.6	Gross Error Cleaning	142
4.6.1	The Reliability of the Adjustment System	143
4.6.2	Data Snooping	145
4.6.3	The Iteration Method with Selected Weights	145
4.6.4	Iteration with the Selected Weights from Robust Estimation	146
4.6.5	Iteration Supervised by Posteriori Variance Estimation.	149
4.7	Graphic and Image Cleaning	151
4.7.1	The Correction of Radiation Deformation	151
4.7.2	The Correction of Geometric Deformation	154
4.7.3	A Case of Image Cleaning	155
	References	155
5	Methods and Techniques in SDM	157
5.1	Crisp Set Theory	157
5.1.1	Probability Theory	157
5.1.2	Evidence Theory	159
5.1.3	Spatial Statistics	160
5.1.4	Spatial Clustering	161
5.1.5	Spatial Analysis	161
5.2	Extended Set Theory	162
5.2.1	Fuzzy Sets	163
5.2.2	Rough Sets	164
5.3	Bionic Method	165
5.3.1	Artificial Neural Network	165
5.3.2	Genetic Algorithms	166
5.4	Others	167
5.4.1	Rule Induction	167
5.4.2	Decision Trees	169
5.4.3	Visualization Techniques	169
5.5	Discussion	169
5.5.1	Comparisons	170
5.5.2	Usability	170
	References	171

6	Data Field	175
6.1	From a Physical Field to a Data Field	175
6.1.1	Field in Physical Space	176
6.1.2	Field in Data Space	177
6.2	Fundamental Definitions of Data Fields	178
6.2.1	Necessary Conditions	178
6.2.2	Mathematical Model	179
6.2.3	Mass	179
6.2.4	Unit Potential Function	180
6.2.5	Impact Factor	181
6.3	Depiction of Data Field	182
6.3.1	Field Lines	182
6.3.2	Equipotential Line (Surface)	182
6.3.3	Topological Cluster	184
	References	185
7	Cloud Model	187
7.1	Definition and Property	187
7.1.1	Cloud and Cloud Drops	187
7.1.2	Properties	188
7.1.3	Integrating Randomness and Fuzziness	188
7.2	The Numerical Characteristics of a Cloud	189
7.3	The Types of Cloud Models	190
7.4	Cloud Generator	192
7.4.1	Forward Cloud Generator	192
7.4.2	Backward Cloud Generator	194
7.4.3	Precondition Cloud Generator	196
7.5	Uncertainty Reasoning	196
7.5.1	One-Rule Reasoning	197
7.5.2	Multi-rule Reasoning	198
	References	201
8	GIS Data Mining	203
8.1	Spatial Association Rule Mining	203
8.1.1	The Mining Process of Association Rule	204
8.1.2	Association Rule Mining with Apriori Algorithm	205
8.1.3	Association Rule Mining with Concept Lattice	207
8.1.4	Association Rule Mining with a Cloud Model	211
8.2	Spatial Distribution Rule Mining with Inductive Learning	215
8.3	Rough Set-Based Decision and Knowledge Discovery	222
8.3.1	Attribute Importance	223
8.3.2	Urban Temperature Data Mining	224
8.4	Spatial Clustering	231
8.4.1	Hierarchical Clustering with Data Fields	233
8.4.2	Fuzzy Comprehensive Clustering	235
8.4.3	Mathematical Morphology Clustering	243

- 8.5 Landslide Monitoring. 245
 - 8.5.1 SDM Views of Landslide Monitoring Data Mining. 245
 - 8.5.2 Pan-Concept Hierarchy Tree 248
 - 8.5.3 Numerical Characters and Rules 248
 - 8.5.4 Rules Plus Exceptions 253
- References. 255
- 9 Remote Sensing Image Mining 257**
 - 9.1 RS Image Preprocessing 257
 - 9.1.1 Rough Set-Based Image Filter 258
 - 9.1.2 Rough Set-Based Image Enhancement 258
 - 9.2 RS Image Classification 260
 - 9.2.1 Inductive Learning-Based Image Classification 260
 - 9.2.2 Rough Set-Based Image Classification 264
 - 9.2.3 Rough Set-Based Thematic Extraction 267
 - 9.3 RS Image Retrieval 268
 - 9.3.1 Features for Image Retrieval 268
 - 9.3.2 Semivariogram-Based Parameter to Describe Image Similarity. 269
 - 9.3.3 Image Retrieval for Detecting Train Deformation 271
 - 9.4 Facial Expression Image Mining 274
 - 9.4.1 Cloud Model-Based Facial Expression Identification. 275
 - 9.4.2 Data Field-Based Human Facial Expression Recognition 278
 - 9.5 Brightness of Nighttime Light Images as a Proxy 281
 - 9.5.1 Brightness of Nighttime Lights As a Proxy for Freight Traffic. 282
 - 9.5.2 Evaluating the Syrian Crisis with Nighttime Light Images. 284
 - 9.5.3 Nighttime Light Dynamics in the Belt and Road. 288
 - 9.6 Spatiotemporal Video Data Mining 290
 - 9.6.1 Technical Difficulties in Spatiotemporal Video Data Mining. 291
 - 9.6.2 Intelligent Video Data Compression and Cloud Storage 292
 - 9.6.3 Content-Based Video Retrieval 292
 - 9.6.4 Video Data Mining Under Spatiotemporal Distribution. 293
 - References. 296
- 10 SDM Systems 299**
 - 10.1 GISDBMiner for GIS Data 299
 - 10.2 RSImageMiner for Image Data 300
 - 10.3 Spatiotemporal Video Data Mining 304
 - 10.4 EveryData. 305
 - References. 308