

Contents

Chapter 1	Introduction	1
1.1	Why Does 3D GIS Matter?	1
1.2	The Needs for 3D GIS	3
1.3	The Need for 3D Spatial Data Modeling	7
1.4	Problems Associated with Spatial Modelling for 3D GIS	9
1.5	Previous Work	10
1.6	Background to the 3D GIS Problem	13
Chapter 2	An Overview of 3D GIS Development	15
2.1	GIS Functions	15
2.2	3D GIS	16
2.3	Recent Progress Made on 3D GIS	17
2.4	Commercially Available Systems and 3D GIS	18
2.4.1	ArcView 3D Analyst	18
2.4.2	Imagine VirtualGIS	19
2.4.3	GeoMedia Terrain	20
2.4.4	PAMAP GIS Topographer	21
2.5	Why is 3D GIS Difficult to Realise?	22
2.6	Discussion	23
Chapter 3	2D and 3D Spatial Data Representations	25
3.1	Introduction	25
3.2	Classes of Object Representations	26
3.2.1	Grid	26
3.2.2	Shape Model	27
3.2.3	Facet Model	28
3.2.4	Boundary Representation (B-rep)	30
3.2.5	3D Array	32
3.2.6	Octree	33
3.2.7	Constructive Solid Geometry (CSG)	34
3.2.8	3D TIN (Tetrahedral network, TEN)	35
3.3	GIS Applicability of the Representations	37
3.4	The Selection Criteria	38
3.4.1	Representation of Object Primitives	38

	3.4.2	Topology of Spatial Objects: Simplexes and Complexes	40
	3.5	Vector and Raster Representations	41
	3.6	Summary	42
Chapter 4		The Fundamentals of Geo-Spatial Modelling	43
	4.1	Spatial Data	44
	4.2	Spatial Data Modeling	44
	4.3	Models and Their Importance for Geoinformation	45
	4.4	Components of Geo-spatial Model	47
	4.5	Phases in Geo-spatial Modeling	48
	4.6	Conceptual Design of a Geo-spatial Model	50
	4.6.1	Definition of Space	51
	4.6.2	Abstraction of Space	52
	4.6.3	Abstraction of Real World Object	53
	4.6.4	Object and Spatial Extent	57
	4.6.5	Spatial Relations	57
	4.6.6	Application of Spatial Relations	62
	4.6.7	Representation of Spatial Objects and Relationships	65
	4.6.8	Spatial Data Models in GIS	73
	4.7	Logical Design of Geo-spatial Model	78
	4.7.1	Relational Approach	79
	4.7.2	Object-oriented Approach	81
	4.8	Summary	85
Chapter 5		The Conceptual Design	87
	5.1	TIN-based (2.5D) Data Model	87
	5.2	Properties of the TIN-based Data Model	90
	5.3	TEN-based Data Model	94
	5.4	Generalized n-dimensional Integrated Data Model	97
	5.4.1	The Definitions	98
	5.5	Single-theme and Multi-theme	101
	5.6	Euler's Characteristics	102
	5.6.1	Euler's Equality	103
	5.6.2	The Generalized Euler Equality	104
	5.7	Discussion	107

Chapter 6	The Logical Design	109
6.1	Relational Approach	109
6.1.1	Relational Data Structure for TIN-based Model	110
6.1.2	Relational Data Structure for a TEN-based Model	112
6.1.3	Relational Data Structure for an n-dimensional Data Model	115
6.2	Object-oriented Approach	116
6.2.1	Object-oriented Definition of a Spatial Object	117
6.2.2	Object-oriented Design Based on IDM	118
6.2.3	Specialization of Classes	120
6.2.4	Aggregation of Objects	125
6.2.5	Creation of Objects	126
6.2.6	Behaviour of Objects in the Database	128
6.2.7	Comparison with Other OO Approaches	129
6.3	Discussion	130
Chapter 7	Object-Oriented TINs Spatial Data	133
7.1	Introduction	133
7.2	Object-oriented Concepts	133
7.2.1	The Abstraction Mechanisms	134
7.2.2	The Programming Language	136
7.3	Object-oriented TIN Tessellations	136
7.3.1	Classes for 2D TIN Tessellations	136
7.3.2	Classes for 3D TIN Tessellations	140
7.4	Object-oriented TINs Spatial Data Modelling	140
7.4.1	The Classes Schema	140
7.5	Object-oriented TIN Spatial Database Development	146
7.5.1	The POET OO DBMS	146
7.5.2	The POET Database Schema	147
7.5.3	The POET Database Browser	148
7.5.4	POET Database Query	148
7.6	Object-oriented TIN-based Subsystems for GIS	149
7.7	Summary	150

Chapter 8	The Supporting Algorithms	153
8.1	Introduction	153
8.2	Distance Transformation	153
8.3	Voronoi Tessellations	158
8.4	Triangulations (TINs)	163
8.4.1	TIN Topological Data Structuring	168
8.5	Visualization	170
8.6	3D Distance Transformation	171
8.7	3D Voronoi Tessellation	176
8.8	Tetrahedron Network (TEN) Generation	181
8.9	Constrained Triangulations	183
8.9.1	The Line Rasterization	183
8.9.2	The Construction of the Constrained TINs	185
8.10	Contouring Algorithm	190
8.10.1	Data Structures for Contouring	190
8.10.2	The Algorithm	192
8.10.3	The Contour Visualization	195
8.11	Algorithms for Irregular Network Formation	196
8.12	Summary	204
Chapter 9	Applications of the Model	207
9.1	Integration of Terrain Relief and Terrain Features	207
9.2	Creating an Integrated Database	209
9.3	A Spatial Query Example	212
9.4	Integrating with 3D Features	214
9.5	Integrating with Geo-scientific Data	219
9.6	Spatial Operators	221
9.7	Graphic Visualization	223
9.7.1	Wireframe Graphics	224
9.7.2	Hidden Line and Surface Removal	225
9.7.3	Surface Shading and Illumination	226
9.7.4	Texture Mapping	227
9.8	Virtual Reality	230
9.9	Discussion	230

Chapter 10	The Web and 3D GIS	233
	10.1 Introduction	233
	10.2 Web 3D GIS	234
	10.3 Management of 3D Spatial Data	238
	10.4 GUI for 3D Visualization and Editing on the Web	240
	10.5 Current and Possible Approaches in Urban Planning	248
	10.6 Realized Browser-based Solutions	249
	10.7 Stand-alone Solutions/Toolkits/Front-ends	254
	10.8 Summary	255
Chapter 11	Conclusion and Further Outlook	257
	11.1 Summary	257
	11.2 Further Research	264
	References and Bibliography	267
	Index	287