
CONTENTS

Foreword	x
Preface	xiii
1 Geographical Information Systems and Graphical Information	1
1.1 Basic Concepts	1
1.2 Socioeconomic Challenges	12
1.3 Benefits of Computerizing Information	21
1.4 Users of GIS	25
2 Historical Development: Geographical Data and GIS	27
2.1 Early Developments	27
2.2 First Automatic Processing of Geographical Information	31
2.3 The Microprocessor	32
2.4 Recent Developments	34
3 From the Real World to GIS	36
3.1 The Real World	36
3.2 Real-World Model	36
3.3 Data Model	37
3.4 Levels of Measurement	45
3.5 From Database to GIS to Map	46
3.6 Extension of the Traditional GIS Data Model	46
3.7 Conceptual Generalization	50
3.8 Role of Maps in Data Modeling	51
3.9 Extension of the Reality Concept	52
4 Basic Data Models	54
4.1 Introduction	54
4.2 Vector Data Model	55
4.3 Raster Data Models	73
4.4 Automatic Conversion Between Vector and Raster Models	84
4.5 Vector Versus Raster Models	86
4.6 Attribute Data and Computer Registers	87
4.7 Linking Digital Map and Attribute Information	91

5	Advanced Data Models	94
5.1	Terrain Surface Representation	94
5.2	Three-dimensional Objects	102
5.3	Representation of Time	105
5.4	Models for Movable Objects	108
5.5	Combination of Models	111
6	Georeferencing Systems	112
6.1	Datum	113
6.2	Coordinate Systems	115
6.3	Map Projection	118
6.4	UTM	119
6.5	Coordinate Conversion and Transformation	121
6.6	Elevation Referencing	123
6.7	Relative Georeferencing	125
6.8	Discrete Georeferencing Systems	127
7	Hardware and Communication Technology for GIS Applications	130
7.1	Computers	130
7.2	Networks	133
7.3	Displays	137
7.4	Quantizers	139
7.5	Plotters and Other Output Devices	142
8	Basic Software and Databases for GIS	146
8.1	The Foundation Stones of GIS Software	146
8.2	Operating Systems	148
8.3	Communications Between Users and Computers	148
8.4	Database Management Systems	152
8.5	Computer-Aided Design	164
8.6	Multimedia	164
8.7	World Wide Web	166
8.8	User Requirements	168
8.9	Working Environment	169
9	Data Collection I	170
9.1	Introduction	170
9.2	Digitizing Maps	171
9.3	Scanning	176
9.4	Manual Digitizing or Scanning	184
9.5	Aerial Photographs and Photo Interpretation	185
9.6	Remote Sensing	187
10	Data Collection II	199
10.1	Surveying	199
10.2	Satellite Positioning System	201

10.3	Photogrammetric Mapping	207
10.4	Collection of Attribute Data	210
10.5	Text Data	214
11	Data Quality	215
11.1	Selection Criteria	215
11.2	Measuring Accuracy and Precision	218
11.3	Resolution and Sampling Rate	222
11.4	Data Storage Precision	223
11.5	Positional Accuracy	223
11.6	Attribute Data Accuracy	225
11.7	Temporal Accuracy	227
11.8	Logical Consistency	228
11.9	Completeness	230
11.10	Data Quality Overview Elements	231
11.11	Accessibility	232
11.12	Probable Sources of Error	232
11.13	Quality Control	234
12	Database Implementation and Spatial Indexing	235
12.1	Database	235
12.2	Distributed Databases	239
12.3	Databases for Map Data and Indexing	240
12.4	Partitioning and Indexing	241
12.5	Database Design	244
13	Housekeeping Tools	251
13.1	Introduction	251
13.2	Data-Entry Functions	253
13.3	Importing Existing Digital Data	253
13.4	Organization of Data Storage Operations	254
13.5	Functions for Correcting and Adapting Geometric Data for Further Use	256
13.6	Editing and Correcting Attribute Data	263
14	Basic Spatial Analysis	265
14.1	Analysis of Spatial Information	265
14.2	Logic Operations	266
14.3	General Arithmetic Operations	267
14.4	General Statistical Operations	268
14.5	Geometric Operations	268
14.6	Search and Report Generation from Attribute Data	273
14.7	Geometric Data Search and Retrieval	274
14.8	Complex Operations of Attribute Data	275
14.9	Classification and Reclassification	277

14.10	Integrated Processing of Geometry and Attributes	278
14.11	Overlay	279
14.12	Buffer Zones	283
14.13	Raster Data Overlay	284
14.14	Procedures in Integrated Data Analyses	285
15	Advanced Analysis	288
15.1	Network and Raster Connectivity Operations	288
15.2	Spatial Interpolation and Proximity Operations	292
15.3	Fuzzy Analysis	297
15.4	GIS Analytic Models	297
15.5	Practical Application of GIS Analytical Functions	300
15.6	Digital Terrain Models	304
15.7	Hydrologic Modeling	309
15.8	Functions for Engineering GIS	311
16	Visualization	313
16.1	Theoretical Foundation	314
16.2	Graphic Generalization	322
16.3	Selecting Map Symbols	323
16.4	Limitations and Potentials of GIS in Cartographic Communications	324
16.5	Final Comments	327
17	Choosing a GIS: Organizational Issues	329
17.1	Technology and Organization	329
17.2	Phases in Organizational Issues	333
17.3	Development of a Business Concept and the Identification of Goals	334
17.4	Appraisal of Current Tasks, Users, Data, and Data Flow	335
17.5	Review of Others' Experience with GIS	336
17.6	Identification of User Requirements	337
17.7	Financial Evaluations—Cost-Benefit Analyses	339
17.8	Developing a Strategic Plan	345
17.9	Developing a Logical Data Model	357
17.10	Creating National Geographic Databases and Developing New Business Sectors	358
18	Choosing a GIS: Technical Issues	361
18.1	Pilot Project	361
18.2	Choosing Hardware and Software for GIS	362
18.3	Contracts	371
18.4	Technical Database Design	372
18.5	Creating a Database	373
18.6	System Operation and Maintenance	374

18.7	Safekeeping and Security Routines	374
18.8	Evaluating New Applications	376
19	Standards and Geospatial Infrastructure	377
19.1	Introduction to Standards	377
19.2	Elements for Standardization	380
19.3	Standard Transfer Formats	382
19.4	Special Standardization Elements	387
19.5	Standardization on the Application Level	389
19.6	Metadata	392
19.7	Infrastructure for Georeferenced Data	397
19.8	Data Access and Digital Libraries	401
20	Formal Problems in Establishing GIS	403
20.1	Ownership and Copyright	403
20.2	Cost Recovery and Pricing	404
20.3	Public or Private Organization of Geodata	406
20.4	Example of Strategy for a National Map Service	407
20.5	Data Security	408
21	A Vision for the Future	409
	References	414
	Index	417