

The cover art depicts a satellite in orbit above the Earth. The satellite is positioned in the center-right, with its solar panels extended. A bright light source, likely the sun, is behind the satellite, creating a lens flare effect. The Earth is visible on the left side of the cover, showing a portion of its blue and white surface. The background is a dark space filled with stars.

Second Edition

ADVANCED SURVEYING

TOTAL STATION, GPS, GIS AND REMOTE SENSING

**Satheesh Gopi
R. Sathikumar
N. Madhu**

 **Pearson**

About Pearson

Pearson is the world's learning company, with presence across 70 countries worldwide. Our unique insights and world-class expertise comes from a long history of working closely with renowned teachers, authors and thought leaders, as a result of which, we have emerged as the preferred choice for millions of teachers and learners across the world.

We believe learning opens up opportunities, creates fulfilling careers and hence better lives. We hence collaborate with the best of minds to deliver you class-leading products, spread across the Higher Education and K12 spectrum.

Superior learning experience and improved outcomes are at the heart of everything we do. This product is the result of one such effort.

Your feedback plays a critical role in the evolution of our products and you can contact us - reachus@pearson.com. We look forward to it.

ADVANCED SURVEYING

Total Station, GPS, GIS and Remote Sensing

Second Edition

Satheesh Gopi

Deputy Chief Hydrographer
and Chartered Engineer
Hydrographic Survey Wing
Kerala Port Department
Thiruvananthapuram

R. Sathikumar

Principal (Retired)
Government Engineering College
Burton Hill
Thiruvananthapuram

N. Madhu

Professor (Retired)
Civil Engineering Department
College of Engineering
Thiruvananthapuram

Copyright © 2018 Pearson India Education Services Pvt. Ltd

Published by Pearson India Education Services Pvt. Ltd, CIN: U72200TN2005PTC057128, formerly known as TutorVista Global Pvt. Ltd, licensee of Pearson Education in South Asia.

No part of this eBook may be used or reproduced in any manner whatsoever without the publisher's prior written consent.

This eBook may or may not include all assets that were part of the print version. The publisher reserves the right to remove any material in this eBook at any time.

ISBN 978-93-528-6072-2

eISBN 978-93-528-XXXX-X

Head Office: A-8 (A), 7th Floor, Knowledge Boulevard, Sector 62, Noida 201 309, Uttar Pradesh, India.

Registered Office: Module G4, Ground Floor, Elnet Software City, TS-140, Block 2 & 9, Rajiv Gandhi Salai, Taramani, Chennai 600 113, Tamil Nadu, India.

Fax: 080-30461003, Phone: 080-30461060

www.pearson.co.in, Email: companysecretary.india@pearson.com

BRIEF CONTENTS

<i>Preface</i>	<i>xxi</i>
<i>Acknowledgements</i>	<i>xxiii</i>
<i>About the Authors</i>	<i>xxv</i>
CHAPTER 1 Fundamental Concepts of Geographic Information System	1
CHAPTER 2 GIS Data Models	20
CHAPTER 3 Data Acquisition	39
CHAPTER 4 Maps and Map Projections	56
CHAPTER 5 The Coordinate System	85
CHAPTER 6 Spatial Analysis	102
CHAPTER 7 Application of GIS	115
CHAPTER 8 Basics of Total Station	146
CHAPTER 9 Electronic Distance Measurements	159
CHAPTER 10 Surveying Using Total Station	183
CHAPTER 11 Data Collection Procedures	219
CHAPTER 12 Automatic Level, Digital Level and Optical Theodolites	229
CHAPTER 13 Aerial Surveying	247
CHAPTER 14 Fundamentals of Remote Sensing	287

CHAPTER 15	Basics of Global Positioning System	339
CHAPTER 16	Surveying Using Global Positioning System	369
	<i>Appendix A: Basic Geodetic Aspects</i>	415
	<i>Appendix B: Sample Equipment Procedure of Various Equipment</i>	420
	<i>Appendix C: Sokkia Total Station CX Series, Field Procedure</i>	430
	<i>Appendix D: Topcon Total Station GTS/100N, Cygnus, Set0n Series</i>	442
	<i>Index</i>	449

CONTENTS

<i>Preface</i>	<i>xxi</i>
<i>Acknowledgements</i>	<i>xxiii</i>
<i>About the Authors</i>	<i>xxv</i>
CHAPTER 1 Fundamental Concepts of Geographic Information System	1
1.1 Introduction	1
1.2 Various Definitions of GIS	4
1.3 Ordinary Mapping to GISs	5
1.4 Comparison of GIS with CAD and Other Systems	6
1.4.1 Land Information System	7
1.4.2 Automated Mapping and Facility Management	8
1.4.3 GIS-T	8
1.5 GIS Architecture (GIS Subsystems)	8
1.5.1 Data Input	8
1.5.2 Data Storage and Retrieval	9
1.5.3 Data Manipulation and Analysis	9
1.5.4 Data Output	10
1.6 Components of a GIS	11
1.6.1 Hardware	11
1.6.2 Software	11
1.6.3 Data	11
1.6.4 People	12
1.6.5 Methods	12
1.7 The Four Ms	12
1.8 GIS Work Flow	13
1.9 Fundamental Operations of GIS	14
1.10 Levels of Use of a GIS	14
1.11 Objective of GIS	15
1.12 The Theoretical Framework of a GIS	16
1.13 Accuracy in a GIS	16
1.14 Data Exploration	16
1.15 Thematic Layering	16
1.16 Levels of Measurement in GIS	17
1.17 Categories of GIS	18
1.18 Topology	18
<i>Review Questions</i>	<i>19</i>

CHAPTER 2	GIS Data Models	20
2.1	Introduction	20
2.2	GIS Data Types	21
	2.2.1 Spatial Data	21
	2.2.2 Attribute Data	22
2.3	Spatial Data Models	22
2.4	Vector Data Model	22
2.5	Raster Data Model	24
2.6	Image Data	27
2.7	Vector and Raster—Advantages and Disadvantages	28
2.8	Attribute Data Models	29
	2.8.1 Tabular Model	30
	2.8.2 Hierarchical Model	30
	2.8.3 Network Model	31
	2.8.4 Relational Model	31
	2.8.5 Object-Oriented Model	33
2.9	Digital Elevation Model	33
	2.9.1 The Availability of DEM Data	34
2.10	Digital Elevation Models and Geographic Information Systems	34
2.11	Applications of DEM	34
	2.11.1 Scientific Applications	35
	2.11.2 Commercial Applications	36
	2.11.3 Industrial Applications	36
	2.11.4 Operational Applications	36
2.12	Data Structure for Continuous Surface Model	37
	<i>Review Questions</i>	38
CHAPTER 3	Data Acquisition	39
3.1	Data Acquisition in Geographic Information System	39
3.2	Analog Maps	39
3.3	Aerial Photographs	40
3.4	Satellite Imagery	41
3.5	Ground Survey	42
3.6	Global Positioning System	42
3.7	Reports and Publications	43
3.8	Digitizers (for Vector Data Input)	43
	3.8.1 The Map Digitizing Operation	44
	3.8.2 Major Problems of Map Digitization	45
	3.8.3 Advantages of Digitized Storage	45
3.9	Scanners (for Raster Data Input)	45
3.10	Digital Mapping by Aerial Photogrammetry	47
3.11	Remote Sensing with Satellite Imagery	47
3.12	Rasterization	47
3.13	Vectorization	48
3.14	Advanced Technologies for Primary Data Acquisition	49

3.15	Digital Mapping by Aerial Photogrammetry	49
3.16	Digital Data Acquisition	50
3.17	Data Processing	50
3.17.1	Media Conversion	50
3.17.2	Geographic Data Conversion	51
3.17.3	Registration/Coordinate Transformation	51
3.17.4	Tiling and Edge Matching	51
3.18	Digitizing Issues	51
3.19	Functions of GIS	52
3.19.1	Compilation	52
3.19.2	Storage	52
3.19.3	Manipulation	52
3.19.4	Output	53
3.20	Spatial Data Relationships	53
3.21	Topologic Data	54
3.22	Comparison of Analog Map versus Digital Map	55
	<i>Review Questions</i>	55
CHAPTER 4	Maps and Map Projections	56
4.1	Introduction	56
4.2	Types of Maps	57
4.2.1	Cadastral Maps	58
4.2.2	Topographic Maps	58
4.2.3	Thematic Maps	59
4.2.4	Remotely Sensed Images	61
4.3	Scale of a Map	62
4.4	Representing the Scale of a Map	63
4.5	Map Symbols	63
4.6	Uses of Maps	64
4.7	Characteristics of Maps	64
4.8	Map Projection	65
4.9	An Ideal Map Projection	66
4.10	Projection Characteristics	66
4.10.1	Features of Various Projections	66
4.11	The Standard Parallel and Standard Meridian	67
4.12	Different Map Projections	67
4.12.1	Map Projection According to the Development of Surface	67
4.12.2	Map Projection According to the Method of Deviation (Source of Light)	71
4.12.3	Map Projection According to the Global Properties	71
4.13	Construction of Map Projection	71
4.14	Cylindrical Map Projection	71
4.14.1	Cylindrical Map Projection Characteristics	72
4.14.2	Types of Cylindrical Projection	72
4.15	Conical Projections	76
4.15.1	Properties of Conical Projection	76

4.15.2	Equidistant Conic Projection	76
4.15.3	Simple Conic	77
4.15.4	Lambert Conformal Conic Projection	78
4.16	Azimuthal Projections	78
4.16.1	Normal Azimuthal Projections	79
4.16.2	The Gnomonic Projection	79
4.16.3	Stereographic Projection	80
4.16.4	Orthographic Projection	81
4.16.5	Equidistant Projection	82
4.16.6	Lambert Equivalent Projection	82
	<i>Review Questions</i>	83
CHAPTER 5	The Coordinate System	85
5.1	Introduction	85
5.2	Plane Coordinate Systems	85
5.3	Plane Cartesian Coordinates	86
5.4	Plane Polar Coordinates	87
5.5	Cartesian 3D Coordinate Systems	87
5.6	Geographic Coordinate Systems	88
5.7	Projected Coordinate Systems	89
5.7.1	The Elevation	90
5.8	Astronomical Coordinate Systems	90
5.9	Geoid and Reference Ellipsoids	91
5.10	Cartography	91
5.10.1	Traditional Cartography	92
5.10.2	Computer Cartography	92
5.11	GPS Mapping	92
5.12	Transformation Methods	92
5.12.1	Analytical Transformation	93
5.12.2	Direct Transformation by the Grid-on-Grid Method	95
5.12.3	Numerical Transformation Methods	98
5.13	Factors Influencing the Choice of Suitable Map Projections	100
	<i>Review Questions</i>	101
CHAPTER 6	Spatial Analysis	102
6.1	Introduction	102
6.2	Classification of Analytic Functions of a GIS	102
6.2.1	Measurement, Retrieval and Classification Functions	103
6.2.2	Spatial Selection Queries	106
6.2.3	Classification	108
6.3	Overlay Function	109
6.3.1	Vector Overlay	109
6.3.2	Raster Overlay	110
6.3.3	Arithmetic Operators	111
6.3.4	Logical Operators	112

6.3.5 Neighbourhood Function	113
6.4 Network Analysis	113
<i>Review Questions</i>	<i>114</i>
CHAPTER 7 Application of GIS	115
7.1 Introduction	115
7.2 Some Applications of GIS	116
7.2.1 GIS in Environmental Fields	116
7.2.2 GIS in Forestry	116
7.2.3 GIS in Hydrology	117
7.2.4 Military Application	117
7.2.5 GIS in Health Management	117
7.2.6 GIS in Geology	118
7.2.7 GIS in Business	118
7.2.8 GIS in Infrastructure and Utilities	118
7.2.9 GIS in Land Information	119
7.2.10 GIS in Computer Cartography	119
7.2.11 GIS in Agriculture	119
7.2.12 GIS in Archaeology	119
7.2.13 GIS in Fisheries	120
7.2.14 GIS in Civil Engineering	120
7.2.15 GIS in Transportation Engineering	121
7.2.16 GIS in Traffic Engineering	121
7.3 GIS Application Areas and User Segments	122
7.4 Custom GIS Software Application	123
7.4.1 Custom GIS	123
7.4.2 User Interface	124
7.5 Usability Engineering in the GIS Domain	124
7.6 Important GIS User Interface Issues	125
7.7 Geographic Visualization	125
7.8 Geographic Query Languages	126
7.8.1 Compatibility and Portability of Systems	126
7.8.2 Future GIS User Interfaces	126
7.8.3 Internet Use	127
7.8.4 Object Orientation	127
7.8.5 Portable Computing	127
7.8.6 Real Time Access to High-Resolution Satellite Data	127
7.9 Guidelines for the Preparation of a GIS	127
7.10 Application of GIS for Land Use and Housing Management	136
7.11 Application of GIS in the Assessment of Physical Transformation of an Urban Area	137
7.11.1 Land Use and Activities of an Urban Area	138
7.11.2 Application of GIS Possibilities and Limitations	138
7.12 Application of GIS—Case Studies	139
<i>Review Questions</i>	<i>145</i>

CHAPTER 8	Basics of Total Station	146
8.1	Introduction	146
8.2	Advantages of Total Station	150
8.3	Disadvantages of Total Station	150
8.4	Measuring Angles	150
8.5	Types of Total Stations	152
8.6	Advancement in Total Station Technology	152
8.7	Automatic Target Recognition	155
8.8	Imaging Scanning and Robotic Total Station	155
8.9	Hybrid Robotic Total Station	157
8.10	Reflectorless Measurement	157
8.11	Built in Software	158
	<i>Review Questions</i>	<i>158</i>
CHAPTER 9	Electronic Distance Measurements	159
9.1	Introduction	159
9.2	Measurement Principle of EDM Instrument	159
	9.2.1 Distance Measurement Technique	162
	9.2.2 Classification of EDM	163
9.3	EDM Instrument Characteristics	165
	9.3.1 Different Wavelength Bands Used by EDM	166
9.4	Errors in EDMs	166
9.5	Error Correction in EDMs	168
9.6	Zero Correction	169
	9.6.1 Prism Integer	169
	9.6.2 Error by Incidence Angle	170
9.7	Reflector Used for EDMs	171
	9.7.1 Prisms Used for EDMs	172
	9.7.2 Reflector-less EDMs	173
9.8	Accuracy in EDMs	174
9.9	Field Procedure of EDM	174
9.10	Geometry of EDMs	175
9.11	EDM without Reflecting Prisms (Reflector Less Measurements)	178
9.12	Focussing and Sighting	179
9.13	EDM Accuracies	179
9.14	Direct Reflex EDM Technology	180
	9.14.1 Time-of-Flight (Pulsed Laser) Measurement	180
	9.14.2 Phase-Shift Measurement	181
	9.14.3 Comparison of the Two Methods	181
	9.14.4 Laser Safety Standards	181
	<i>Review Questions</i>	<i>182</i>
CHAPTER 10	Surveying Using Total Station	183
10.1	Introduction	183
10.2	Fundamental Parameters of Total Station	185

10.2.1	Parameters for Calculation	185
10.2.2	Correction Factors and Constants	185
10.3	Precautions to be Taken While Using a Total Station	188
10.4	Field Equipment	188
10.5	Total Station Set Up	190
10.6	Setting Up a Back Sight	192
10.7	Azimuth Mark	192
10.8	Measurement with Total Station	193
10.9	Total Station Initial Setting (General Setting Required for all Models)	193
10.10	Field Book Recording	194
10.11	Radial Shooting	194
10.12	Traverse	195
10.13	Survey Station or Shot Location Description Using Codes	195
10.14	Occupied Point (Instrument Station) Entries	197
10.15	Data Retrieval	199
10.16	Field Generated Graphics	200
10.17	Construction Layout Using Total Stations	201
10.18	Overview of Computerized Survey Data Systems	204
10.19	Data Gathering Components	204
10.20	Data Processing Components of the System	206
10.21	Data Plotting	206
10.22	Equipment Maintenance	206
10.23	Maintaining Battery Power	207
10.24	Total Station Job Planning and Estimating	208
10.25	Error Sources of Electronic Theodolite	209
10.26	Total Survey System Error Sources and How to Avoid Them	211
10.27	Controlling Errors	212
10.28	Field Coding	214
10.29	Field Computers	214
10.30	Modem for Data Transfer (Field to Office)	215
10.31	Trigonometric Levelling and Vertical Traversing	216
10.32	Trigonometric Levelling—Field Procedures	216
10.33	Trigonometric Levelling—Error Sources	217
10.34	Application of Total Station	217
	<i>Review Questions</i>	218
CHAPTER 11	Data Collection Procedures	219
11.1	General	219
11.2	Functional Requirements of a Generic Data Collector	220
11.3	Data Collection Operating Procedures	220
11.4	Responsibility of the Field Crew for Data Collection and Processing	222
11.5	Interfacing the Data Collector with a Computer	223
11.6	Digital Data	224
11.7	Digital Transfer of the Data to Application Software	224
11.8	Requirements of a Data Collector	226
11.9	Coding of Field Data While Using a Data Collector	227

11.10	Summary of Data Collector Field-to-Finish Procedures	227
11.11	Data Collection in Modern Total Stations	228
	<i>Review Questions</i>	228
CHAPTER 12	Automatic Level, Digital Level and Optical Theodolites	229
12.1	Automatic Level	229
12.2	Digital Level	231
	12.2.1 Advantages of Digital Levels	232
	12.2.2 Components of Digital Level	232
12.3	Micro-Optical Theodolites (Micrometre Theodolite)	233
	12.3.1 General Description of a Micro-Optical Theodolite	234
	12.3.2 Centering the Theodolite with the Optical Plummet	236
12.3.3	Focussing and Sighting	237
12.3.4	Reading Angles	237
12.3.5	Measuring Single Angles	239
12.3.6	Measuring Sets of Directions	239
12.3.7	Measuring Vertical Angles	240
	12.3.8 Measuring Vertical Angles with the Three Wire Method	240
	12.3.9 Tacheometric Observation	241
	12.3.10 Horizontal Collimation Error and Its Adjustments	241
	12.3.11 Vertical Collimation Error (Index Error) and Its Adjustments	242
12.4	Digital Planimeter	243
12.5	Laser Distance Metre (Laser Range Finder)	245
	<i>Review Questions</i>	246
CHAPTER 13	Aerial Surveying	247
13.1	General Background	247
13.2	Terrestrial Photogrammetry	248
13.3	Aerial Photogrammetry	248
13.4	Photographing Devices	249
	13.4.1 Metric Cameras	249
	13.4.2 Stereo Metric Camera	251
13.5	Aerial Photographs	251
	13.5.1 Information Recorded on Photographs	252
13.6	Photographic Scale	252
13.7	Photo Interpretation	254
13.8	Flying Heights and Altitude	255
13.9	Mapping from Aerial Photography	256
13.10	Relief Displacement (Radial Displacement)	257
13.11	Tilt Displacements	259
13.12	Correction of Relief and Tilt	260
13.13	Flight Planning	261
13.14	Planning Flight Lines and Layout of Photography	261
13.15	Coverage of the Photograph	263

13.16	Ground Control for Mapping	265
13.16.1	Number of Photographs	266
13.16.2	Interpretation of Photos	266
13.17	Mosaics	267
13.18	Stereoscopy	268
13.19	Lens Stereoscope and Mirror Stereoscope	270
13.20	Parallax	272
13.20.1	Parallax Bar and Measurement of Parallax	273
13.21	Aerial Triangulation	275
13.22	Radial Triangulation	275
13.20.1	The Slotted Template Method	275
13.20.2	Radial Line Plotter	276
13.23	Photogrammetric Techniques	277
13.23.1	Mapping from a Single Photograph	278
13.23.2	Stereo Photogrammetry	279
13.23.3	Mapping from Several Photographs	280
13.24	Photogrammetric Stereoscopic Plotting Techniques	280
13.25	LIDAR	281
13.26	Applications of LIDAR	283
13.27	Hyperspectral Imagery	284
13.28	Orthophoto	285
	<i>Review Questions</i>	286
CHAPTER 14	Fundamentals of Remote Sensing	287
14.1	Concept of Remote Sensing	287
14.2	Principles of Remote Sensing	288
14.3	Components of Remote Sensing	289
14.4	Seven Elements in Remote Sensing	290
14.5	Characteristics of Electromagnetic Radiation	291
14.6	Electromagnetic Spectrum	294
14.6.1	IR Region and Wein's Displacement Law	296
14.7	Transmission Path	298
14.7.1	Atmospheric Windows	299
14.7.2	Scattering of Electromagnetic Radiation	299
14.8	Platforms	301
14.8.1	Ground-Based Platforms	302
14.8.2	Aerial Platforms	302
14.8.3	Satellite Platforms	303
14.9	Types of Remote Sensing	303
14.10	Passive Remote Sensing	304
14.10.1	Thematic Mapper	305
14.11	Active Remote Sensing	305
14.11.1	Doppler Radar	306
14.11.2	Precipitation Radar	306

14.12	Thermal IR Remote Sensing	306
14.12.1	Stefan–Boltzmann Law and Temperature–Energy Relationships	306
14.13	Detectors	308
14.14	Thermal IR Imaging	308
14.15	Applications of Thermal IR Imaging	309
14.16	Imaging with Microwave Radar (Microwave Remote Sensing)	309
14.17	Radiometry and Photometry	310
14.18	Black Body Radiation	310
14.19	Reflectance	312
14.20	Remote Sensing Systems	313
14.21	Scanner	313
14.21.1	Across–Track (Whiskbroom) Scanners	313
14.21.2	Along–Track (Push–Broom) Scanners	314
14.22	Multispectral Scanner	314
14.23	Electro-optical Sensors	314
14.24	Signature	314
14.25	Resolution and GRE	315
14.26	Pixel Size and Scale	318
14.27	Satellite Orbital Characteristics, and Swaths	318
14.28	Instantaneous Field of View	319
14.29	Major Satellite Programmes	320
14.30	Weather Monitoring Satellite Sensors	321
14.31	The Principle Steps Used in Remotely Sensed Data Analysis	321
14.32	Data Reception, Transmission, and Processing	322
14.33	Interpretation and Analysis	323
14.33.1	Manual and Digital Interpretation	324
14.34	Elements of Visual Interpretation	324
14.35	Digital Image Processing	327
14.35.1	Preprocessing	328
14.35.2	Image Enhancement	329
14.35.3	Image Transformations (Multiimage Manipulation)	329
14.35.4	Image Classification and Analysis	330
14.35.5	Data Integration and Analysis	330
14.36	Remote Sensing in India	331
14.36.1	Remote Sensing Satellites of India	331
14.36.2	Data from IRS Satellites	335
14.36.3	NNRMS	335
14.36.4	Advanced Remote Sensing Satellites	336
	<i>Review Questions</i>	337
CHAPTER 15	Basics of Global Positioning System	339
15.1	Introduction	339
15.2	Overview of GPS	340
15.3	GPS Segments	340

15.3.1	The Space Segment	341
15.3.2	The Control Segment	342
15.3.3	The User Segment	343
15.4	Satellite Ranging	343
15.5	Pseudo-Range and Pseudo-Random Code	346
15.6	GPS Broadcast Message and Ephemeris Data	347
15.7	Time Calculation	348
15.8	Position Calculation	349
15.9	Positioning Services	352
15.9.1	SPS	352
15.9.2	PPS	352
15.10	Current GPS Satellite Constellation	352
15.11	GPS Errors and Their Corrections	352
15.11.1	Ephemeris Errors and Orbit Perturbations	354
15.11.2	Clock Stability	354
15.11.3	Ionospheric Delays	355
15.11.4	Troposphere Delays	357
15.11.5	Signal Multipath	358
15.11.6	Satellite and Receiver Clock Errors	359
15.11.7	Selective Availability	360
15.11.8	Anti-Spoofing (A-S)	361
15.11.9	Receiver Noise	361
15.12	User Equivalent Range Error	361
15.12.1	Geometric Dilution of Precision	362
15.12.2	Positional Dilution of Precision	363
15.12.3	Horizontal Dilution of Precision	364
15.12.4	Vertical Dilution of Precision VDOP	364
15.13	Pseudo-Range Observation Equation	364
15.14	Carrier Phase Observation Equation	366
15.15	Mask Angle	366
	<i>Review Questions</i>	367
CHAPTER 16	Surveying Using Global Positioning System	369
16.1	Introduction	370
16.2	Difference between GPS Navigation and GPS Surveying	371
16.3	Characteristics of GPS Surveying and GPS Navigation	371
16.4	Accuracy Requirements in GPS Surveying	372
16.5	Absolute and Relative Positioning	372
16.6	Absolute Positioning with the Carrier Phase	372
16.7	Pseudo-ranging	373
16.8	Differential Positioning	376
16.9	Differential Pseudo-Range Positioning (Differential Code-Based Positioning)	377
16.10	Differential Positioning (Carrier Phase Tracking)	378
16.11	Ambiguity Resolution	379

16.12	General Field Survey Procedures for Surveying Using GPS	379
16.13	Absolute Point Positioning	381
16.13.1	Navigation Receivers	381
16.13.2	Mapping Grade GPS Receivers	381
16.14	Different Methods Used in GPS Surveying (Differential Positioning by Carrier Phase Tracking)	382
16.14.1	GPS Antenna for Absolute and Relative Measurements	382
16.15	Important Points for a GPS Survey Solution	383
16.16	Static Surveying Method	383
16.16.1	Equipment for Instrument Station for Static Surveying	384
16.16.2	Static Survey Methodology	385
16.16.3	Static Survey Field Procedures	387
16.16.4	General Checklist for Onsite Procedures	388
16.16.5	General Check List for Monitoring the GPS Receiver While Surveying	389
16.16.6	Applications of Static Method of Survey	389
16.17	Rapid Static or Fast Static Method	389
16.17.1	Reoccupation Mode in Rapid Static Survey	390
16.18	The Stop-and-Go Technique in Kinematic Method	390
16.18.1	Antenna Swap Calibration Procedure	391
16.19	Kinematic Surveying Method (True Kinematic)	392
16.20	Pseudo-Kinematic GPS Survey	394
16.21	Kinematic On-the-Fly (OTF)	395
16.22	Real-Time Kinematic Surveying (RTK)	395
16.23	Real-Time Differential GPS Code Phase Horizontal Positioning GPS	396
16.24	Office Procedures after Data Collection	399
16.25	Post-Processing of Differential GPS Data	399
16.26	Differential Reduction Technique	400
16.26.1	Single Differencing between Receivers	401
16.26.2	Single Differencing between Satellites	401
16.26.3	Single Differencing between Epochs	401
16.26.4	Double Differencing	402
16.26.5	Triple Differencing	402
16.27	Baseline Solution by Cycle Ambiguity Recovery	403
16.28	Baseline Processing	403
16.29	Standard GPS Data Format	404
16.29.1	RINEX Format	404
16.29.2	The RTCM SC-104 Message Format	404
16.29.3	NMEA Format	404
16.30	Accuracy of GPS Height Differences	404
16.31	Topographic Mapping with GPS	405
16.32	Cycle Slip	405
16.33	Latency	406
16.34	GPS Augmentation	406
16.34.1	Ground-Based Augmentation System	406
16.34.2	Satellite-Based Augmentation System	406

16.35 Wide Area Augmentation System	407
16.36 European Geostationary Navigation Overlay Service	408
16.37 MTSAT Satellite-Based Augmentation Navigation System	408
16.38 GPS-Aided GEO Augmented Navigation System	408
16.39 Global Navigation Satellite System	408
16.40 GNSS Classification	408
16.41 Early Ground-Based Positioning Systems	409
16.42 Need for GNSS	410
<i>Review Questions</i>	411
 <i>Appendix A: Basic Geodetic Aspects</i>	415
<i>Appendix B: Sample Equipment Procedure of Various Equipment</i>	420
<i>Appendix C: Sokkia Total Station CX Series, Field Procedure</i>	430
<i>Appendix D: Topcon Total Station GTS/100N, Cygnus, Set0n Series</i>	442
<i>Index</i>	449

PREFACE

Surveying is fundamental to all civil engineering activities, which include construction of buildings, roads, railways, bridges, dams, canals, airports and harbours. Survey data is the integral part of design and execution of all engineering projects. Time is very important in the present scenario and advanced surveying techniques employ precise electronic surveying instruments that are capable of performing most accurate data collection in short time.

There have been far rapider advancements in the area of surveying compared with other divisions of civil engineering. During the last two decades, developments in electronics and optics have led to significant advancements in surveying instruments and techniques. The conventional equipment such as compass, vernier theodolites, dumpy levels have given way to versatile modern digital instruments such as digital levels, electronic theodolites, electronic distance measuring devices, total stations, Global Positioning Systems (GPS) and LIDAR. The traditional surveying techniques were completely replaced by advanced techniques. Manual methods were completely replaced by advanced computerized data collection, digital processing and computer-aided drafting and mapping systems. Modern techniques had evolved with the introduction of satellite-based remote sensing systems and Global Navigational Satellite Systems (GNSS). The field of surveying had undergone rapid changes due to the introduction of most modern electronic instruments and widespread adoption: total station, GPS, digital levels and geographical information systems (GISs). With the introduction of the latest instruments mentioned above and advanced techniques made the preparations of survey maps is very simple and precise.

The main aims of compiling this book is to provide the knowledge of modern techniques and modern instruments such as total station, electronic distance measuring (EDM), GPS and LIDAR and the knowledge of GIS in a comprehensive manner for civil engineering students as well as practicing engineers.

In this new edition, a major organizational change has been done. The revised edition has been specially written keeping in mind the requirements of undergraduate students of engineering. Most of the subject prescribed in undergraduate curricula of civil engineering has been covered in an easy to comprehend manner. This book is also useful to students pursuing GIS. The book deals with modern instruments and techniques used in the field of geoinformatics.

Content of the book is as follows: The book has been organized into four sections. The first part discusses the Fundamentals of GIS, Applications of GIS, Map Projection and Coordinate Systems. The second part deals with the Principles of Total Station, EDM, Surveying Using Total Station and detailed descriptions of most modern surveying equipment such as digital level, micro-optic theodolites, LIDAR and terrestrial scanner. The third part deals with Photogrammetry and Aerial Surveying in detail. The fourth part covers Basics of GPS and Surveying Using GPS. Appendix A deals with the basic Geodetic Aspects required for GPS-based surveying. Appendices B–D provide step-by-step field procedure of various models of total stations.

The detailed structure of the book is as follows:

Chapter 1 presents the fundamental concepts of GIS such as GIS architecture, components of GIS and GIS work flow and categories of GIS.

Chapter 2 discusses about the GIS data models such as spatial, vector, raster and attribute data models. The chapter also discusses digital elevation model (DEM), image data and application of DEM.

Chapter 3 deals with data acquisition in GIS using analogue maps, aerial photographs, satellite imagery, ground surveys, GPS, etc. The chapter also focuses on digitizers, scanners as a source of data input, rasterization and vectorization using various equipment and methods.

Chapter 4 provides details on maps and map projection. It narrates the characteristics of maps, different map projections and construction of map projection.

Chapter 5 presents various coordinate systems in detail. It also covers geoid and reference ellipsoids, and different transformations.

Chapter 6 is devoted to spatial analysis. It presents classification of analytic of GIS, overlay function and network analysis.

Chapter 7 covers various applications of GIS including case studies.

Chapter 8 deals with the basics of total station.

Chapter 9 focuses on measuring principle of EDM, characteristics of EDM, field procedure of EDM and various types of EDMs.

Chapter 10 describes execution of field surveys using total station, which includes field procedures, overview of computerized survey data systems, total station job planning and estimating and trigonometric levelling.

Chapter 11 elaborates data collection procedures to be followed while surveying using total station.

Chapter 12 covers most modern surveying instruments such as automatic levels, digital levels, micro-optic theodolites, LIDAR, digital planimeters and laser levels.

Chapter 13 deals with aerial surveying and details about aerial photogrammetry, terrestrial photogrammetry, different photogrammetric techniques and LIDAR.

Chapter 14 presents the fundamentals of remote sensing.

Chapter 15 deals with the basics of GPS.

Chapter 16 introduces the modern methods of surveying using GPS.

Lecture PPTs are available for download from the Instructor Resource centre at www.pearsoned.co.in/satheeshgopi

Satheesh Gopi
R. Sathikumar
N. Madhu

ACKNOWLEDGEMENTS

We are extremely grateful to the editorial team of M/s. Pearson Education for the excellent effort they made to bring out the revised edition of the book. We wish to thank M/s. Tosh-nitek International, Chennai for providing catalogues of various modern survey equipment and step-by-step field procedures of Sokkia total station. Despite of our best efforts, it is possible that some errors may be unnoticed and we shall be grateful if these are brought to our notice.

We would like to thank all those reviewers who took out time to go through the book and gave us their valuable feedback. Their names are as follows:

K. Nirmalkumar

Professor
Kongu Engineering College, Tamil Nadu

Tapas Karmaker

Assistant Professor
Thapar University, Punjab

M. Vijai Kishore

Assistant Professor
University of Petroleum and Energy Studies,
Uttarakhand

H. B. Nagaraj

Professor
B.M.S. College of Engineering, Karnataka

Bhavna Tripathi

Associate Professor and Head of Department
Vivekananda Institute of Technology, Rajasthan

Narendra Kumar

Professor
Poornima University, Rajasthan

Abhijit M. Zende

Assistant Professor
Dr. Daulatrao Aher College of Engineering,
Maharashtra

Kuldeep Singh

Assistant Professor
Radharaman Engineering College,
Madhya Pradesh

Reshma Raskar Phule

Assistant Professor
Sardar Patel College of Engineering,
Maharashtra

N. Gladwin Gnana Asir

Associate Professor
Dr. Sivanthi Aditanar College of Engineering,
Tamil Nadu

Goutam Bairagi

Professor
Jalpaiguri Government Engineering College,
West Bengal

Mukul C Bora

Professor
Dibrugarh University Institute of Engineering
and Technology, Assam

Deepak Kumar Mandal

Professor
University of North Bengal, West Bengal

Satheesh Gopi
R. Sathikumar
N. Madhu

ABOUT THE AUTHORS

Satheesh Gopi, the principal contributor to this book, has over 27 years' experience as a hydrographer and is currently a Deputy Chief Hydrographer in the Hydrographic Survey Wing of Kerala Port Department. He graduated in civil engineering from the College of Engineering, Thiruvananthapuram and holds master's degree in Construction Engineering and Management from Anna University, Chennai. He also holds master's degrees in Information Technology, and Disaster Management. He has worked with the Survey Department of Government of Dubai for 5 years as a Senior Hydrographer.



He is the author of the book *Global Positioning System – Principle and Applications* and *Basic Civil Engineering*. He has published research papers on global positioning system, advanced surveying, digital cartography and hydrography in various journals of national repute. Most of his research papers were presented in international conferences, such as International Federation of Surveyors (FIG), International Hydrographic Organization (IHO) and Map Middle East. He has worked as guest faculty in reputed engineering colleges and universities. He is a member of Institution of Engineers and life member of Indian Cartographic Association.

R. Sathikumar is currently the Principal, at the Rajadhani Institute of Engineering and Technology, Thiruvananthapuram. He retired from the Government service as Principal, Government College of Engineering, Burton Hill, Thiruvananthapuram. He received his post-graduate degree, in Transportation Engineering from IIT Kanpur in 1989 and also pursued his Ph.D. from IIT Roorkee in 1996.

N. Madhu is a retired Professor (Civil) from the College of Engineering, Thiruvananthapuram. He obtained his M.Tech. in Traffic and Transportation Engineering from IIT Madras in 1991.

FUNDAMENTAL CONCEPTS OF GEOGRAPHIC INFORMATION SYSTEM

1

Chapter Outline

- 1.1 Introduction
- 1.2 Various Definitions of GIS
- 1.3 Ordinary Mapping to GISs
- 1.4 Comparison of GIS with CAD and Other Systems
- 1.5 GIS Architecture (GIS Subsystems)
- 1.6 Components of a GIS
- 1.7 The Four Ms
- 1.8 GIS Workflow
- 1.9 Fundamental Operations of GIS
- 1.10 Levels of Use of a GIS
- 1.11 Objective of GIS
- 1.12 The Theoretical Framework of a GIS
- 1.13 Accuracy in a GIS
- 1.14 Data Exploration
- 1.15 Thematic Layering
- 1.16 Levels of Measurement in GIS
- 1.17 Categories of GIS
- 1.18 Topology

1.1 INTRODUCTION

GIS stands for *geographic information system*. An information system is a computer program that manages data. A GIS is a type of information system that deals specifically with geographic, or spatial, information. GIS is a rapidly growing technological field that incorporates graphical features with tabular data to assess real-world problems. The GIS began to develop in the 1960s, with the discovery that maps could be programmed using simple code and then stored in a computer, allowing future modifications when necessary. This was a marvellous change from the era of hand cartography when maps had to be created by hand. The earliest version of a GIS was known as computer cartography and involved simple line work to represent land features. From that evolved the concept of overlaying different mapped features on top of each other to determine patterns and causes of spatial phenomena.

The capabilities of GIS have been known from the simple beginnings of computer cartography. At the simplest level, GIS can be thought of as a high-tech equivalent of a map. Paper maps cannot be produced for quicker and more effective storage of data. An easily accessible digital format of maps in GIS enables complex analysis and modelling of data, which was previously not possible with paper maps. The reach of GIS expands into all disciplines and has been used in wide range, such as prioritizing sensitive species habitat, and determining optimal real-estate locations for new businesses.

The keyword to GIS technology is geography. This means that the data, or at least some proportion of the data, are spatial; or in other words, data in some way referred to the locations on earth. Geographic information describes the spatial or location factors of an object or area. This can simply be latitude and longitude, but in most cases more complex factors are included.

A GIS allows users to view, update, query, analyse, combine and manipulate map data. It can take information from different maps and tables and register them to a desired base. It can manage large collections of natural resources and environmental data and the complex data sets needed for urban studies. It can overlay maps to eliminate or include areas based on multiple layers of tabular criteria. It can automatically generate buffers around features such as sensitive land use types.

A GIS operates on many levels. At basic level, it is used as computer cartography for automated mapping. The real power in GIS is through using spatial and statistical methods to analyse attributes and geographic information. The end result of the analysis can be derivative, interpolated or prioritized information.

A GIS can be made up of a variety of software and hardware tools. The important factor is the level of integration of these tools, which provide a smooth operating and fully functional geographic data processing environment. GIS should be viewed as a technology, and not simply as a computer system. GIS provides facilities for data capture, data management, data manipulation and analysis, and the presentation of results in both graphic and report form. It provides a particular emphasis on preserving and utilizing inherent characteristics of spatial data. Today, GIS is a multi-billion-dollar industry employing hundreds of thousands of people worldwide. GIS is taught in schools, colleges and universities throughout the world. Professionals and domain specialists in every discipline are becoming increasingly aware of the advantages of using this technology for addressing their unique spatial problems.

GIS provides the necessary set of tools required for gaining the appropriate insights into the places and processes that drive our environment, society and economy. It provides the means of finding hidden patterns and trends that would have remained undetected using conventional means of looking at data, by combining data from a variety of different sources such as corporate, commercial and government databases, images from cameras and satellites, and data derived from any type of sensor or human observation, and presenting it in the form of a map. GISs are not restricted to the conventional view of geography, that is, that of people and places on the earth's surface. Hidden geographies lie everywhere, and a GIS is the perfect tool to take on voyages of discovery. GIS will help to pave the way for the success of the expedition by providing the means of visualizing and exploring these uncharted territories.

Computer revolution and the advent of cheap desktop computers made an explosion in the use and availability of GIS. GISs are no longer the sole domain of scientists funded by generous research grants, but are available to everyone from a small shop owner to a major corporation at a highly competitive price, allowing virtually anyone to become a player in the global marketplace through the insights fuelled by the geo-revolution. Our perception is built upon the ability to distinguish boundaries and outlines, and effectively store them in our brains as mental images. Thus, maps with their clear and concise definition of area and space provide ample food for thought, a crystal clear concept provided by reams of data in a spreadsheet.

Dr John Snow's well-known cholera map is one of the earliest known examples of GIS. In September 1854, during an outbreak of cholera in a section of the city of London, Dr John Snow, a local physician, decided to test his hypothesis that cholera is a waterborne disease and that the outbreak was a result of contaminated water supplies—a view contrary to the medical beliefs of the time—by drawing a map showing where the victims lived and where the local water pumps were

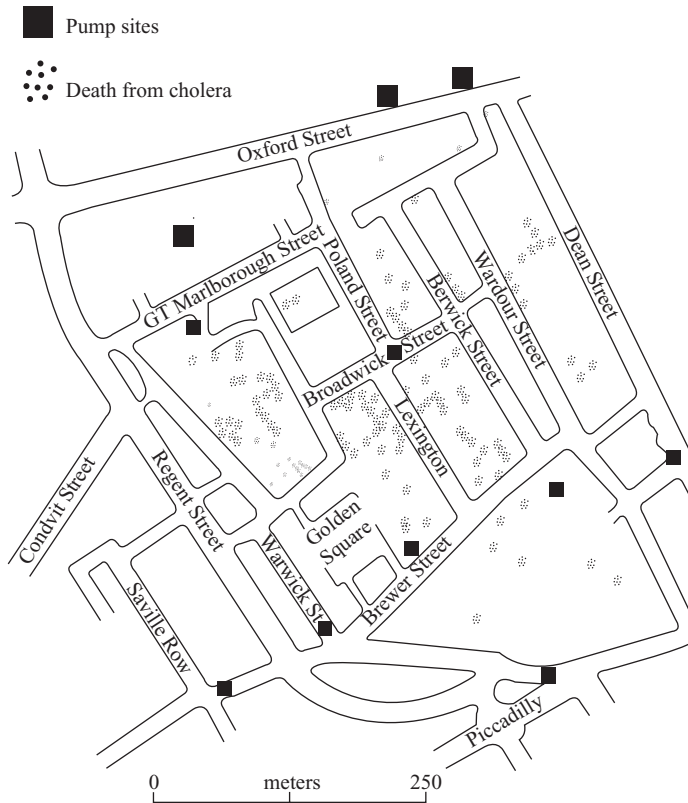


FIGURE 1.1 The first GIS used for identifying an epidemic disease

located (see Fig. 1.1). The map clearly showed a clustering of cholera cases around one of the pumps, and when that pump was shut down, the outbreak stopped. Using the simple means of pen and paper, Dr Snow was able to prove a cause and effect relationship between a contaminated supply of water and instances of disease by using a map to visualize the instances of disease and the location of water pumps. This mapping in epidemiology is cited as the first example to highlight the application of geographic analysis.

GISs, backed by the power of modern computers, allow us to benefit from the visual power of maps and to transcend the limitations of the past. Paper maps, for all their beauty and communicative power, are limited; they are static representations of the world, and the result of a great amount of effort. GIS maps, on the other hand, are dynamic; users can pan, zoom, turn layers on or off, change the scale and their point of perspective a thousand times without any effort at all. The data in a GIS are dynamic and constantly change as new data become available in the system, and through the enormous power of modern computers, a GIS can turn out thousands of maps representing the data from millions of records at a minimum amount of time.

The introduction of topological techniques permitted the data to be connected in a relational sense, in addition to their spatial connections. Thus, it became possible not only to determine where a point (e.g., a hydrant) or a line (e.g., a road) or an area (e.g., a stadium, park) was located, but also to analyse those features with respect to their relation to other special features, connectivity

(network analysis) and direction of vectors. The present generation GIS is distinguished from geo-processing of the past by the use of computer automation to integrate geographic data processing tools in a friendly and comprehensive environment.

The advent of sophisticated computer techniques have proliferated the multidisciplinary application of geo-processing methodologies, and provided data integration capabilities that were logistically impossible before. The ability to incorporate spatial data, manage and analyse it, and answer spatial questions are the distinctive characteristics of GIS.

GIS is now becoming an independent discipline in the name of geomatics, geoinformatics or geospatial information science and is used in many departments of government and university.

1.2 VARIOUS DEFINITIONS OF GIS

The GIS is a rapidly growing technology and has been defined in various ways. The following definition of GIS gives a concise description of the term/system: a GIS is a computerized, integrated system used to compile, store, manipulate and output mapped spatial data.

Different definitions of Geographic Information System given by various organizations are as follows:

- Geographic information system, commonly referred to as a GIS, is an integrated set of hardware and software tools used for the manipulation and management of digital spatial (geographic) and related attribute data.
- Geographic information system (GIS) is a computer-based tool for mapping and analysing things that exist and events that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps.
- GIS is an integrated system of computer hardware, software and trained personnel linking topographic, demographic, utility, facility, image and other resource data that are geographically referenced.
- Geographic information system (GIS) is a computer-based information system that enables capturing, modelling, manipulation, retrieval, analysis and presentation of geographically referenced data.

GIS has become an essential part of day-to-day life. People might have not realized about its applications on everyday life. If someone uses an Internet mapping program to find directions, they are actually using a GIS. A new supermarket chain on the corner was probably located using GIS to determine the most effective place to meet customer demand. The system-based definition of GIS may be called 'functional', because it is based on the functions that a GIS performs. As each of these functions is performed on the geographic data associated with the GIS, the definition may also be called 'data-centred'.

From the above definitions, the following observations can be made:

1. GIS database use geo-references as a primary mean to store and access information.
2. GIS integrates technology.
3. GIS can be viewed as a process rather than software/hardware.
4. GIS helps to make better and quick decisions.

1.3 ORDINARY MAPPING TO GISs

Topographic features called as entities have a long history of being portrayed on scaled maps and plans. These maps or plans provided an inventory of scaled or general features that were found in a given geographic area. With the emergence of large databases, which were collected primarily for mapping, attention was given to a new technique for analysing and querying the computer-stored data, which later became the GIS. GIS data can be assembled from existing databases, digitized or scanned from the existing maps and plans, or collected using conventional surveying techniques or by using the global positioning system (GPS).

A GIS is a system which uses geo-referenced data to answer questions. A computer-assisted cartographic system is a set of graphic elements for map display and printing, and is not a GIS. A computer-aided-drafting (CAD) system is a set of graphic elements for engineering and architectural design in which some have GIS modules as add-ons.

GIS is an integrated multidisciplinary science consisting of the following traditional disciplines such as geography, cartography, statistics, remote sensing, computer science, photogrammetry, mathematics, operational research, surveying, civil engineering, geodesy and urban planning. Table 1.1 summarizes how the above disciplines make up GIS with respect to the functions. GIS has many alternative names used over the years with respect to the range of applications and emphasis, as listed below:

1. Land Information System (LIS)
2. AM/FM—Automated Mapping and Facilities Management

TABLE 1.1 Relations of traditional disciplines with GIS

Discipline	Functions of GIS								
	Data Acquisition	Mapping	Pre-Processing	Data Structure	Database	Spatial Analysis	Modeling	Display	Application
Geography		×				×			×
Cartography	×	×						×	×
Remote sensing	×	×				×		×	×
Photogrammetry	×	×						×	×
Surveying	×	×							
Geodesy		×							
Statistics			×		×	×			
Operational research						×	×		
Computer science			×	×	×	×	×		
Mathematics				×		×	×		
Civil engineering	×	×				×	×		
Urban planning	×					×	×		×

3. Environmental Information System (EIS)
4. Resources Information System
5. Planning Information System
6. Spatial Data Handling System

The ability to store data on feature-unique layers permits the simple production of special feature maps. In a GIS, spatial entities have two characteristics, namely, the location and attributes. Coordinates, street address, etc. can give the location and attributes and describe some characteristics of the feature being analysed. GIS has now blossomed into a huge and diverse field of activity. Most activities can be identified as being in one of the two broad fields:

1. Geographic feature-specific activities such as mapping, engineering, environment, resources and agriculture.
2. Cultural or social activities such as market research, census, demographics and socio-economic studies.

The switch from hard copy maps to computerized GIS has provided many benefits. This system can help to do the following:

1. Store and easily update large amount of data.
2. Sort and store spatial features called entities into thematic layers. Data are stored in layers so that complex spatial data can be manipulated and analysed efficiently by layer, rather than trying to deal with the entire database at the same time.
3. Zoom into sections of the displayed data to generate additional graphics, which may be hidden at default scales.
4. Query items of interest to obtain tables of attribute information that may have been tagged to specific points of interest.
5. Analyse both entities and their attribute data using sophisticated computer programs.
6. Prepare maps showing selected thematic layers of interest. One can update maps quickly as new data are assembled.
7. Import stored data (both spatial and non-spatial) electronically from different agencies, and thus save the costs of collecting data.
8. Use the stored data to prepare maps at different scales, for a wide range of purposes.
9. Build and augment a database by combining digital data from all the data-gathering techniques, that is, from surveying, remote sensing, map digitization, scanning and from the Internet.
10. Create new maps by modelling or re-interpreting existing data.

1.4 COMPARISON OF GIS WITH CAD AND OTHER SYSTEMS

Both GIS and CAD are computer based, but CAD is often associated with high-precision engineering and surveying applications, and GIS is more often associated with the lower levels of precision usually required for mapping and planning.

CAD is similar to mapping because it is essentially an inventory of entered data and computed data that can provide answers to the questions: What is it? Where it is located? But CAD has no

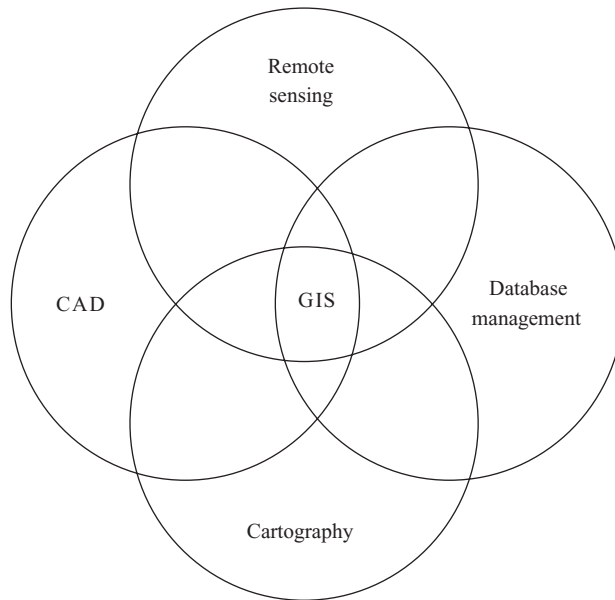


FIGURE 1.2 Relationship of GIS to other main systems

analytical tools to perform spatial analysis. On the other hand, in addition to answering the where and what questions, GIS can model data and provide answers to the spatial and other questions like what occurred? what if? and what patterns exist? Topology gives GIS the ability to determine spatial relations, such as adjacency and connectivity between physical features or entities.

For establishing a definition of GIS, it is important to outline the relationship of GIS with CAD, computer cartography, database management systems (DBMS) and remote sensing information systems. The relationship of GIS to the other systems is given in Fig. 1.2. A GIS can be termed as a subset of the four listed technologies as in the figure. A true GIS can be distinguished from other systems by the fact that it can be used to conduct special searches and overlays, which actually generate new information. Typical subsets of geographic feature-specific GIS include LIS, AM/FM and geographic information system for transportation (GIS-T).

1.4.1 Land Information System

LIS is a subsidiary of the GIS. *LIS* is related entirely to land data. It includes information such as size, shape, location, legal description, topography, flood plains, water resources, easements and zoning requirements for each piece of land in the system. The legal descriptions are those bound with the local administration departments. A GIS includes data for a much wider range than that of *LIS*. The GIS includes not only the data mentioned for *LIS*, but also includes such things as soil types, depth of ground water, census data, school bus routes, tax maps, fire, police jurisdiction and so on. With an *LIS*, a user can determine the ownership of property, tax assessments, mortgages, utilities, boundaries, improvements made to the land and other information needed for land appraisal, land acquisition or for other various uses of the land.

1.4.2 Automated Mapping and Facility Management

AM/FM is an important field of GIS activity with macro applications in the management of municipal utilities. Engineers and surveyors can map inventory roadways, pipelines, cables and other municipal infrastructure utilities using AM/FM software programs. These programs also record all relevant characteristics of the utility. For example, in the case of a sewage line the following data have to be recorded: the pipe type, length of run between manholes, inverts and pipe slopes, date of installation and record of maintenance. The program can be designed to issue work orders for a scheduled maintenance automatically and to prepare plans and profiles that show the locations of all services. AM/FM applications manage the physical plant and services of large office and industrial complexes. All services, including electrical, heating, air-conditioning, elevators, fire protection, communications, as well as building design and layout are stored on three-dimensional layer-specific sections of the computer storage.

1.4.3 GIS-T

GIS-T is a subset of GIS. GIS-T refers to the principles and applications of applied GIS to solve transportation problems. GIS can effectively be employed to find, analyse and solve transportation problems. Now GIS-T has been evolved as a specific branch in GIS, to address transportation issues, and now GIS-T has become one of the major applications of GIS. Highway data are usually modelled in vector fashion by digitizing the centre line as lines of arcs and nodes. Lines or arcs join two coordinated points, and nodes are points of intersection with other highway centre lines or other linear features. Highway reference methods are based on the presence or absence of specific attributes to be analysed or displayed, that is, attributes are stored in separate databases categorized by their attribute characteristics.

1.5 GIS ARCHITECTURE (GIS SUBSYSTEMS)

GIS can be understood as a group of subsystems within the framework of a main system. Accordingly, GIS has the following four functional subsystems (see Fig. 1.4):

1. Data input (data input from maps, aerial photos, satellite imageries and from other sources)
2. Data storage and retrieval (data storage retrieval and query)
3. Data manipulation and analysis (data transformation, analysis and modelling)
4. Data output and display (data reporting such as maps, reports and plans)

1.5.1 Data Input

A data input subsystem allows the user to capture, collect and transform spatial and thematic data into digital form. The data inputs are usually derived from a combination of hardcopy maps, aerial photographs, remotely sensed images, reports and survey documents.

There are five types of data entry systems commonly used in a GIS:

1. Keyboard entry (manually entering the data at a computer terminal)
2. Coordinate geometry (entering coordinates of surveyed data using a keyboard)
3. Manual digitizing (widely used method for entering spatial data from maps)

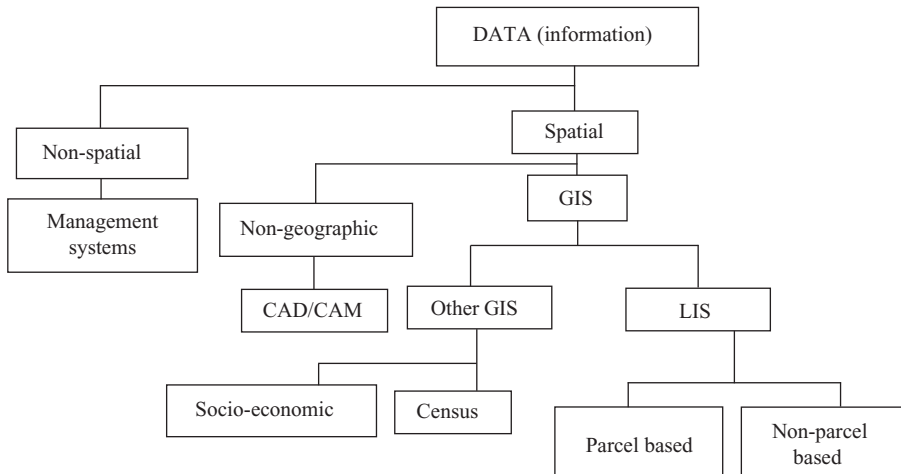


FIGURE 1.3 Flow diagram showing the relation between spatial and non-spatial information with various systems

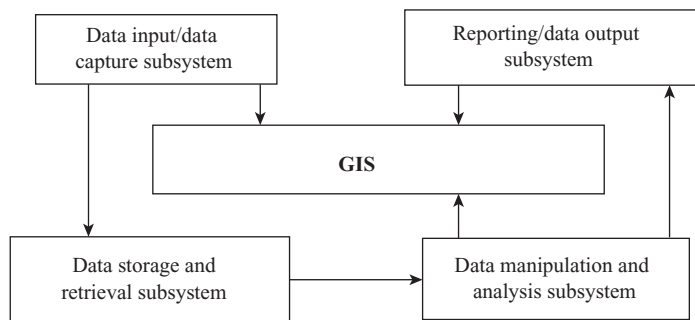


FIGURE 1.4 GIS architecture/GIS subsystems

4. Scanning
5. Input of existing digital files.

1.5.2 Data Storage and Retrieval

The data storage and retrieval subsystem organizes the data, spatial and attribute, in a form which permits it to be quickly retrieved by the user for analysis, and permits rapid and accurate updates to be made to the database. This component usually involves the use of a database management system (DBMS) for maintaining attribute data. Spatial data are usually encoded and maintained in a proprietary file format.

1.5.3 Data Manipulation and Analysis

The data manipulation and analysis subsystem allows the user to define and execute spatial and attribute procedures to generate derived information. This subsystem is commonly thought of as the heart of a GIS, and usually distinguishes it from other DBMS and CAD systems.