

# Contents

<b>Preface . . . . .</b>	<b>xi</b>
<b>Acknowledgments. . . . .</b>	<b>xvii</b>
<b>Introduction . . . . .</b>	<b>xix</b>
<b>Authors. . . . .</b>	<b>xxvii</b>
<b>1 Geometry of the Sphere . . . . .</b>	<b>1</b>
1.1 Introduction.....	1
1.2 Theory: Earth coordinate systems .....	2
1.3 Theory: Earth's seasons—A visual display.....	10
1.4 Theory: Precision of latitude and longitude values .....	12
1.5 Other Earth models.....	17
1.6 Practice using selected concepts from this chapter.....	19
1.6.1 Antipodal points .....	19
1.6.2 Capturing points with a smartphone .....	20
1.6.3 Great circle routes.....	24
1.6.4 Latitude and longitude, hemispheres, and precision.....	26
1.6.5 Final considerations.....	28
1.7 Related theory and practice: Access through QR codes .....	28
<b>2 Location, Trigonometry, and Measurement of the Sphere. . . . .</b>	<b>31</b>
2.1 Introduction: Relative and absolute location.....	32
2.2 Location and measurement: From antiquity to today ....	33

2.3 Practice: Measuring the circumference of the Earth using GPS.....	37
2.3.1 Measuring the Earth's polar circumference using Table 2.1 .....	37
2.3.2 Measuring the Earth's equatorial circumference using Table 2.2 .....	38
2.3.3 For further consideration: Polar circumference and equatorial circumference .....	40
2.3.4 Determining the mass and volume of the Earth using Table 2.3 .....	41
2.4 Measuring positions on the Earth surface, and fractions.....	41
2.5 Other common coordinate systems.....	43
2.6 Practice: Coordinates using different systems .....	47
2.7 Theory: Visual trigonometry review.....	48
2.8 Practice: Find the length of one degree on the Earth-sphere.....	50
2.9 Practice: Determine Sun angles at different seasons of the year.....	51
2.10 Practice: Work with measurement, the graticule, and map projections .....	52
2.11 Summary and looking ahead .....	54
2.12 Related theory and practice: Access through QR codes.....	54

### **3 Transformations: Analysis and Raster/Vector Formats..... 57**

3.1 Transformations .....	58
3.1.1 One-to-one, many-to-one, and one-to-many transformations .....	58
3.1.1.1 Postal transformation.....	61
3.1.1.2 Home ownership.....	61
3.1.1.3 Composition of transformations .....	62
3.1.1.4 Other one-to-many situations .....	63
3.1.2 Geoprocessing and transformations.....	64
3.1.3 QR codes .....	66
3.2 Partition: Point-line-area transformations .....	66
3.2.1 Buffers .....	66
3.2.2 Buffers build bisectors .....	67
3.2.3 Buffers build bisectors and proximity zones .....	68
3.2.4 Base maps: Know your data!.....	69
3.3 Set theory.....	69
3.4 Raster and vector mapping: Know your file formats.....	70
3.4.1 Representing the Earth using raster and vector data .....	73

3.4.2	<i>Vector data resolution: Considerations</i>	74
3.4.3	<i>Raster data resolution: Considerations</i>	75
3.4.4	<i>Determining if a data set is fit for use</i>	76
3.5	<i>Practice using selected concepts from this chapter</i>	77
3.5.1	<i>Drawing buffers from different types of features</i>	77
3.5.2	<i>Geodesic versus Euclidean buffering</i>	78
3.5.3	<i>Siting an Internet café in Denver</i>	79
3.5.4	<i>Data management: Getting data sets and getting them ready for analysis</i>	80
3.5.5	<i>Analyzing your data: Buffers</i>	82
3.6	<i>Related theory and practice: Access through QR codes</i>	84

## 4 Replication of Results: Color and Number . . . 87

4.1	<i>Introduction</i>	87
4.2	<i>Background—Color</i>	88
4.3	<i>Color straws and color voxels</i>	90
4.4	<i>Color ramps: Alternate metrics</i>	94
4.5	<i>Algebraic aspects of ratios</i>	96
4.6	<i>Pixel algebra</i>	98
4.7	<i>Preservation of the aspect ratio</i>	99
4.8	<i>Image security</i>	100
4.9	<i>Theory finale</i>	101
4.10	<i>Practice using selected concepts from this chapter</i>	101
4.10.1	<i>Changing symbol color and size to enhance meaning on maps</i>	101
4.10.2	<i>Identifying and mapping trees for a stream bank erosion control project</i>	104
4.11	<i>Related theory and practice: Access through QR codes</i>	109

## 5 Scale . . . . . 111

5.1	<i>Introduction</i>	112
5.2	<i>Scale change</i>	113
5.3	<i>The dot density map: Theory and example</i>	115
5.3.1	<i>Construction of a dot density map</i>	115
5.3.2	<i>Dot density map theory</i>	118
5.4	<i>Practice using selected concepts from this chapter</i>	120
5.4.1	<i>Scale change exercise</i>	120
5.4.2	<i>Dot density maps: Investigating population change</i>	123
5.4.3	<i>Creating your own dot density maps: Exercise</i>	125
5.5	<i>Related theory and practice: Access through QR codes</i>	126

## **6 Partitioning of Data: Classification and Analysis . . . . . 129**

6.1	Introduction.....	130
6.2	The choice of data ranges .....	130
6.2.1	Natural breaks .....	133
6.2.2	Quantile .....	134
6.2.3	Geometrical interval.....	134
6.2.4	Equal interval.....	134
6.2.5	Standard deviations .....	135
6.3	Normalizing data .....	136
6.4	Inside, outside, wrong side around.....	138
6.5	Making something from nothing?.....	141
6.5.1	Isolines; contours.....	142
6.5.2	Mapplets .....	143
6.6	Practice using selected concepts from this chapter....	145
6.6.1	Investigate classification using ArcGIS online ...	145
6.6.2	Digging deeper into classification using ArcGIS for desktop .....	147
6.6.3	Normalization activity .....	150
6.7	Related theory and practice: Access through QR codes .....	152

## **7 Visualizing Hierarchies . . . . . 155**

7.1	Introduction.....	155
7.2	Hierarchies: Census data .....	157
7.3	Thinking outside the pixel.....	159
7.3.1	Hexagonal hierarchies and close packing of the plane: Overview .....	160
7.3.2	Classical urban hexagonal hierarchies.....	160
7.3.3	Visualization of hexagonal hierarchies using plane geometric figures .....	161
7.3.3.1	Marketing principle .....	161
7.3.3.2	Transportation principle.....	163
7.3.4	Visualization of hexagonal hierarchies using mapplets .....	166
7.4	Practice using selected concepts from this chapter....	167
7.4.1	An introduction to census tabulation areas: Using ArcGIS online for demographic analysis.....	167
7.4.2	Using ArcGIS desktop for demographic analysis.....	170
7.4.3	Denver Internet café analysis .....	172
7.5	Related theory and practice: Access through QR codes.....	174



## **10 Integrating Past, Present, and Future Approaches . . . . . 221**

10.1 Introduction.....	222
10.2 From the classics to the modern: Past and present .....	222
10.3 A non-Euclidean future?.....	227
10.3.1 Projective geometry.....	227
10.3.2 Perspective projections.....	228
10.3.3 Harmonic conjugates.....	228
10.3.4 Harmonic map projection theorem .....	229
10.4 Practice using selected concepts from the chapter.....	232
10.4.1 Examining population change using the gridded population data set.....	232
10.4.2 Network analysis: Offline and online .....	234
10.4.2.1 Offline .....	234
10.4.2.2 Online .....	235
10.4.3 Routing exercise: Determining best route for a tour bus in Manhattan .....	236
10.4.4 Routing exercise: Determining best route for truckling goods across the USA .....	237
10.4.5 Find the busy streets—Denver .....	240
10.4.6 Putting it all together: Practice—Denver Internet café activity .....	241
10.5 Graph theory and topology: Discrete and continuous spatial mathematics.....	243
10.6 Putting it all together: Theory .....	245
10.7 Related theory and practice: Access through QR codes.....	246

## **Glossary . . . . . 247**

## **References, Further Reading, and Related Materials . . . . . 255**



**Update Bank:** [http://www-personal.umich.edu/~sarhaus/  
SpatialMathematics/index.html](http://www-personal.umich.edu/~sarhaus/SpatialMathematics/index.html)

## **Index . . . . . 263**