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Book Review

Spatial Mathematics: Theory and Practice through Mapping by Sandra Lach Arlinghaus and Joseph J. Kerski. Boca Raton, FL: CRC Press, 2014, 300 pp.

I totally agree with the authors' stance that mathematical logic and principles are central to the advent and development of geospatial sciences encompassing geographic information systems (GIS), analytical cartography, spatial data analysis, and more. That a cross-fertilizing process has been going on between mathematics and geospatial sciences also is a very astute observation: the geospatial sciences would not exist without mathematics; "likewise, mathematics would be vastly inhibited without considerations of scale, ratios, angles, directions, patterns, projections, and other spatial concepts" (p. xxii). This argument also holds for the era of spatial analysis, or geography's quantitative revolution (King 1970; Berry, Griffith, and Tiefelsdorf 2008), and will do for any form of future spatially oriented academic endeavors.

Although the book covers a wide range of topics pertaining to the geospatial sciences, its focus is on mapping, as its subtitle suggests; 5 out of the 10 chapters (1, 2, 4, 5, and 9) explicitly address cartographic topics. The rationale presented for this includes (1) "today's mapping is done in a GIS environment" (p. xii); (2) "the core of GIS work is actually visualizing numbers, since the basis for mapping is to represent numbers as cells, points, lines, or polygons on a map" (p. xiii); and (3) "the ability to use such core GIS tools as geoprocessing and spatial statistics hinge[s] upon a solid understanding of the principles and applications of mathematics" (p. xvi).

As a textbook, this publication is quite unique and is not similar to any preexisting textbook that covers similar intellectual terrains with GIS components, including cartography-inclined ones (e.g., Peterson 2009), more spatial data analysis-oriented ones (e.g., Lloyd 2010; O'Sullivan and Unwin 2010; De Smith, Goodchild, and Longley 2011), and more geodesy- and remote sensing-focused ones (e.g., Thurston, Poiker, and Moore 2003; Iliffe and Lott 2008). The integrative and multidisciplinary nature of this book dictates its merits and, at the same time, its limitations. Its merits overwhelmingly come from its providing readers with a comprehensive introduction to fundamental concepts necessary for GIS-based mapping that have been developed in various academic fields. Its limitations are rooted in a lack of adequate in-depth discussions.

Each chapter has its pros and cons. The first two chapters deal with the geodetic characteristics of the earth. Chapter 1 focuses on the earth sphere graticule composed of parallels and meridians and on some other key concepts, such as great circles, the geoid, and reference ellipsoids. Chapter 2 offers a knowledge base for measuring positions on the earth and the circumferences of the earth. Although these two chapters provide readers with some basic ideas about how to represent locations of geographic objects and how to measure some geometric aspects of the earth, the authors could have improved them by including other related concepts. For example, a comparison between the "geocentric" latitude and longitude and their "geodetic" counterparts is extremely important to understand practically how large-scale topographic maps are produced across the world. In addition, the quality of some of the graphics, especially in

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chapter 1, is wanting in terms of resolution and illustrative efficiency. In contrast, the illustration and description of Eratosthenes's measurement of the circumference of the earth is outstanding.

Chapter 3 deals with fundamental concepts for GIS: buffering and a comparison between raster and vector data formats. The authors provide an extremely good introduction to distinctions between the two GIS data formats and their implications in data analysis. In particular, emphasis on the difference between Euclidean buffering and geodesic buffering is an extremely fresh and useful perspective, particularly because the latter rarely has been considered in GIS textbooks, albeit an extremely important topic. Nevertheless, inclusion of other transformation methods, such as data conversion (vectorization and rasterization), spatial selection, overlay operations, and spatial estimation and interpolation would have improved this chapter.

Chapters 4 and 5 deal with two basic concepts for cartographic visualization: color and scale. The authors' lengthy account of color and their description on the relativity of map scale are very appealing: color increasingly has been a focal element for map design; "larger or smaller" scale maps are more adequate terms than "large or small" scale maps. This chapter would have benefited from a further discussion about the concept of scale beyond map scale that includes geographic, measurement, and operational scales (Lam 2004). Understanding their differences and relationships is crucial for students in the field of geospatial sciences. Chapter 6 also deals with another key concept for thematic mapping: data classification. Some representative thematic mapping types, such as proportional or graduated symbol, choropleth, dot density, and isarithmic mapping, should be described in a more systematic way; for example, one presented in accordance with the classification scheme of spatial phenomena in MacEachren (1994). MacEachren's idea is important because his distinction between "spatially discrete" and "spatially continuous" data directly links to the authors' discussion on data normalization.

Chapters 7 and 8 are more concerned with spatial data analysis. Chapter 7 focuses on hierarchical structures in both data and their spatial patterns. Readers may be fascinated by the impressive illustrations of the hierarchical space economy of central place theory. The authors also highlight the importance of the hierarchical nature of socioeconomic data. However, their failure to mention the modifiable areal unit problem is surprising. Chapter 8 is mostly concerned with analytical methods for spatial distributions focusing on linear directional means, mean centers, and standard deviational ellipses. This chapter has the most room for improvement. It also should include global/local spatial autocorrelation measures and some related exploratory spatial data analysis techniques. That one of the most "mathematical" advances in geospatial sciences is totally missing in this book is disappointing.

Chapter 9 deals with the types and characteristics of various map projections. I really like the *Economist* occasion to exemplify the importance of map projection selection. However, the authors should have included certain other topics, such as a comparison between the Robinson and Winkel III projections with the story from the National Geographic Society; the rationale for the compromise projection; major analytical tools for map distortion, such as equal angular distortion and equal areal distortion lines (Canters and Decleir 1989); and excellent map projection tools freely available on the web (e.g., Flex Projector; Jenny, Patterson, and Hurni 2008). Chapter 10 is concerned with new data sets and non-Euclidean concepts for future development. Inclusion of network analysis and some spatial optimization is appealing but should have been extended to a discussion of geocomputational agent-based models.

In conclusion, this book is worth reading by anyone interested in the geospatial sciences. The book has some features that maybe welcomed by young people. First, each chapter begins with a very intuitive and intriguing word cloud, as "an abstract summary of the content of the chapter"

(p. xxiii). Second, each chapter basically is divided into two parts: (1) theory explaining the fundamental concepts and principles in a chapter and (2) practice in terms of examples and applications of material covered in the theory discussion. These two parts collectively help readers, especially beginners, gain a firm understanding of the topics. Third, many of the web references and resources are guided through quick response codes that make it possible for readers to use hypertext and the web via their mobile devices.

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