Uncertainty in Remote Sensing and GIS. Edited by GILES M. FOODY and PETER M. ATKINSON. (Chichester: John Wiley and Sons, 2002). [xviii + 307 pages]. ISBN: 0-470-84408-6. Price £65.00 Hardback.

Geographic information systems are designed to solve problems of practical importance in the real world, but do so based almost entirely on the contents of their databases, rather than the real world itself. Any claim to legitimacy must therefore rest on the success of GIS databases at representing the real world: on the accuracy of measurements and observations incorporated into the database, and on the rigor of the definitions that underlie those measurements and observations. When more than one person is involved in this process, in either creating or using spatial databases, it is also necessary for definitions to be shared among the participants, since such common understanding is vital if the contents of the databases are to be interpreted correctly.

Over the years the collective view of these issues among GIScientists has changed significantly. Early interest was sparked in part by the work of D.H. Maling and by his book *Measurement from Maps* (Maling, 1989), which looked at how the processes of measurement introduced errors that were reflected in uncertainties about the lengths, areas, and other properties of features shown on maps, with obvious parallels to the processes by which GIS could be used to analyze digitized map data. Digitizing itself clearly introduced errors, as did the raster-vector conversions inherent in scanning. But before long it became clear that much more than simple error analysis was involved. Spatial databases have complex spatially autocorrelated error structures, requiring the use of sophisticated theoretical frameworks such as geostatistics, the theory of regionalized variables. Moreover, the definitions used in many mapping tasks are far from rigorous, suggesting that traditional concepts of sets would need to be augmented by fuzzy, rough, and other unconventional notions of sets. Over time the early focus on accuracy and error analysis broadened into a more general concern for uncertainty, and the latter has now become the preferred umbrella term for this field.

This new book is a welcome addition to the large and rapidly growing literature on uncertainty in GIScience. It stems from a conference, and consists of a collection of the conference papers, plus introductory and concluding material. The focus is on remote sensing and its use as a source of data for GIS, and the list of contributors includes some very-well-known names. The book includes a foreword by Paul Curran, first and last chapters by the editors Peter Atkinson and Giles Foody, and fifteen core chapters covering a wealth of topics within the general theme of uncertainty.

Although the title suggests that the entire range of uncertainty issues and approaches will be covered, the remote sensing context leads to greater depth in some areas than others. The famous "five-fold way" of the Spatial Data Transfer Standard (http://mcmcweb.er.usgs.gov/sdts/standard.html) makes a clear distinction between accuracy of attributes and accuracy of position, but in remote sensing there is commonly far more emphasis on the former, and it can be difficult to make accurate measurements of the positioning of pixels on the Earth's surface, especially in the absence of welldefined registration points. Positional accuracy of measurements is covered here only in a short section of one chapter.

The book proceeds in a logical sequence, beginning with an emphasis on the measurement of radiation from the Earth's surface on continuous scales, and its averaging over square pixels. Chapter 1 introduces the major terms associated with accuracy and error of continuous-scale variables. There is relatively little on the uncertainties associated with atmospheric effects, cloud, angle of illumination, or shadow, though Chapter 4 by Manslow and Nixon gives a detailed discussion of the uncertainties associated with variable sensor response within the area nominally covered by a pixel. Chapter 8 by Boyd, Phipps, Duane, and Foody addresses another fundamental source of uncertainty: the use of physical models to infer variation in one variable, based on correlation with another variable that can be sensed directly, using the example of emissivity.

Other chapters move into the uncertainties associated with classification, and the measurement of accuracy for discrete-scale variables. Chapter 5 by Zhan, Molenaar, and Lucieer provides an interesting overview of pixel unmixing methods, which can be seen as a way of addressing a major source of uncertainty in classified scenes, and demonstrates their use with some well-designed test data. Textural algorithms and neural networks form the basis for additional chapters aimed at addressing uncertainty in classification.

At its simplest, accuracy assessment attempts to provide measures that are valid for an entire dataset, that can be included in the dataset's metadata. But in reality accuracies can vary widely across space, and stationarity quickly becomes at best a coarse approximation, and at worst an untenable assumption. Chapter 9 by Smith and Fuller argues that data quality in their context must be regarded as a property of each land parcel, and describe a scheme for associating quality metrics with data at that level.

Given an understanding of uncertainty in raw data, expressed in a suitable model, it should in principle be possible to determine uncertainties in the output of any form of analysis, a task known as propagation. In Chapter 10 Heuvelink argues that uncertainty propagation is often far from simple, and provides some compelling illustrations. Subsequent chapters give examples of uncertainty propagation in models based on remotely sensed data, while Chapter 13 by Wameling and Chapter 14 by Warr, Odeh, and Oliver discuss the effects of uncertainty in raster data on the positions and attributes of derivative vector objects such as boundaries and contours.

In their introductory chapter the editors lay out three objectives for the book: "to (i) discuss the nature of uncertainty; its interpretation, assessment and implications, (ii) assemble a range of up-to-date research on uncertainty in remote sensing and GIScience to show the current status of the field and (iii) indicate future directions for research." As they point out in the final chapter, "We are still a long way from having an 'uncertainty button' in our geographical information systems." The chapters of the book clearly show the power of the geostatistical framework that has come to dominate much research on uncertainty, particularly in remote sensing. At the same time, they demonstrate the growing gap between the sophistication and power of models, and their practical utilization. Whether the answer to better comprehension and greater awareness by the user community lies in better methods of visualization, as some have argued (Hearnshaw and Unwin, 1994), or in the use of such intuitively appealing methods as fuzzy or rough sets (see, for example, the special issue of *Fuzzy Sets and Systems* edited by Cobb, Petry, and Robinson, 2000), which are given remarkably little attention in this book, remains to be seen. But meanwhile, this book is a very useful compendium of research in an important domain of GIScience.

References

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Hearnshaw, H.M., and D.J. Unwin, editors (1994) *Visualization in Geographical Information Systems*. New York: Wiley.

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