MASTERING GIS: TECHNOLOGY, APPLICATIONS AND MANAGEMENT

Integration of GIS and Remote Sensing

EDITOR VICTOR MESEV

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Series Foreword

Since 2001 it has been my privilege to be involved with the book *Geographic Information Systems and Science*, published by John Wiley and Sons, Ltd. Through its various editions, this book and associated materials has sought to present a state-of-the-art overview of the principles, techniques, analysis methods and management issues that come into play whenever the fundamental question 'where?' underpins decision-making.

Together this material makes up the organising concepts of Geographic Information Systems (GIS), which has a rich and varied history in environmental, social, historical and physical sciences. We can think of GIS as the lingua franca that builds upon the common purposes of different academic traditions, but with an additional unique emphasis upon practical problem-solving. As such, much of the core of GIS can be thought of as transcending traditional academic disciplinary boundaries, as well as developing common approaches to problem solving amongst practicing professionals.

Yet many of the distinctive characteristics, requirements and practices of different applications domains also warrant specialised and detailed treatments. 'Mastering GIS' seeks to develop and extend our core understanding of these more specialised issues, in the quest to develop ever more successful applications. Its approach is to develop detailed treatments of the requirements, data sources, analysis methods and management issues that characterise many of the most significant GIS domains.

First and foremost, this series is dedicated to the needs of advanced students of GIS and professionals seeking practical knowledge of niche applications. As such, it is dedicated making GIS more efficient, effective and safe to use, and to render GIS applications ever more sensitive to the geographic, institutional and societal contexts in which it is applied.

Paul Longley, Series Editor
Professor of Geographic Information Science
University of London

Preface

'Integration' refers to the move towards a closer, perhaps symbiotic, relationship between geographic information systems (GIS) and remote sensing and is seen by many to be essential for the future development of both technologies. The main drivers for this move have been the proliferation of geospatial data in various formats, the pursuit of sophisticated statistical models, and the demand for more elaborate applications. Moreover, proprietary systems are no longer solely devoted to either GIS operations or image processing; all now handle data from both and all now offer analytical functions that facilitate dual interoperable analyses.

Ever since the first formal research agendas on GIS and remote sensing integration were introduced, back in 1990, by the US National Center for Geographic Information and Analysis (NCGIA Initiative I-12), hybrid systems have become very much the rule rather than the exception. Although data from both GIS and remote sensing are now routinely analysed by seamless interoperable amalgamated systems, many users are unaware of the numerous technical and institutional issues that need to be addressed when merging data that are derived from disparate sources and essentially represent diametrically opposing conceptual views of reality. This book explores the tremendous potential that lies along the interface between GIS and remote sensing for activating seamless databases and instigating information interchange. It concentrates on the rigorous and meticulous aspects of analytical data matching and thematic compatibility – the true roots of all branches of GIS–remote sensing applications. The first four chapters of the book confront technical issues of integration, such as data fusion, scale effects and data uncertainty, as well as introducing an integrated taxonomy of data structure and system-independent functionality. The remaining chapters explore and demonstrate most of the salient integration procedures and methodologies, using a number of applications, including the measurement of urban morphologies, the estimation of urban sprawl and population growth, urban vulnerability analysis, and the augmentation of environmental change indicators. In all, emphasis is given to the close statistical and thematic association of information from both technologies, and the merits of joint implementation of GIS and remote sensing.

This book is the result of an extensive research by experts working at the interface of GIS and remote sensing and will appeal to students and professionals dealing with not only GIS or remote sensing but also computer science, civil

engineering, environmental science and urban planning in the academic, governmental and commercial/business sectors. The Editor is grateful to all the authors and anonymous reviewers for their time and effort and for keeping to a strict schedule. Acknowledgements are also due to staff at Wiley, especially Fiona Woods and Lyn Roberts, for their patience and encouragement, to Jennifer Miller, Kimberly Hattaway, Aaron Binns, Michael Sims (design cover) and Charles Layman for constructive advice, and to Alexandra Walrath, who painstakingly (and enthusiastically) proofread the entire manuscript, contributed to the Introduction and compiled the Index. Lastly, the editor would like to dedicate this book to Lady Hilda and Sir Geoffrey Miller, who provided guidance and jovial support in abundance.

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GIS and remote sensing integration: in search of a definition

Victor Mesev and Alexandra Walrath

Department of Geography, Florida State University, Tallahassee, FL, USA

Synergy – the bonus that is achieved when things work together harmoniously – Mark Twain

Wisdom implies a mature integration of appropriate knowledge, a seasoned ability to filter the inessential from the essential – Deborah Rozman

1.1 Introduction

Ever since its formalism by the NCGIA Initiative-12 in 1990 (Star *et al.*, 1991), the move towards 'seamless' and 'hybrid' integration of data, techniques and organization from the geographic information systems (GIS) domain with those from the remote sensing[2] sphere has been arduous, sporadic and irresolute. Few major breakthroughs have materialized other than the establishment of routine data format interchanges, improvements in the efficiency of interoperational relational database systems (Abel *et al.*, 1994) and modest advances in the accuracy of object/thematic

[1] GIS is used both singularly and as a collective throughout this book. GIS is typically defined as 'a computer system for the collection, storage, manipulation, display and management of spatial information'.

[2] Remote sensing predominantly refers to the collection and manipulation of digital satellite imagery.

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identification cross-overs (Shi *et al.*, 1999). More ambitious endeavours to create truly *integrated* geographic information systems (IGIS), sometimes called 'total' integration, seem to have floundered on most of the initial conceptual, technical and institutional obstacles identified by the NCGIA initiative (cf. Ehlers, 1989; Star *et al.*, 1990; Hinton, 1996; Wilkinson, 1996; Mesev, 1997). One could even say that the search for more resolute solutions, such as those related to the object/field dichotomy, analytical interoperability, the close monitoring of error propagation and the compatibility of mutually beneficial research programmes, remains as elusive today as it was in 1990. Admittedly, many proprietary geospatial systems are capable of representing and querying data stored in an increasing number of formats and resolutions, yet computational compatibility is rarely translated to full conceptual, thematic, scale and temporal compatibility. In other words, although technical expediency has facilitated the handling of data from GIS and remote sensing, there is no guarantee that any subsequent computational interaction necessarily results in strong intuitive and theoretical mutual relationships. Total integration may not be a question of whether GIS and remote sensing *can* be integrated, but more of whether they *should* be integrated – and to answer that, some discussion is first required on precisely what integration between GIS and remote sensing actually means.

1.2 In search of a definition

No one definition of integration between GIS and remote sensing exists. Instead, integration has been used to refer indiscriminately to almost any type of connection, ranging from pragmatic computational amalgamation of data to the conceptual understanding of how geographic features are interrelated. Unsurprisingly, an unbounded definition embraces a large and growing body of literature, anything from research on tight, seamless databases, and robust statistical relationships (Zhou, 1989; Smits, 1999), to applications of variable implicitness and unpredictable levels of information exchange (cf. de Brouwer *et al.*, 1990; Janssen *et al.*, 1990; Davis *et al.*, 1991; Chagarlamundi and Ganulf, 1993; Debinski *et al.*, 1999; Driese *et al.*, 2001; Brivio *et al.*, 2002). However, in the search for a narrower definition, any book with the term 'integration', to all intents and purposes, presumes a strict discussion on numerical calculations and complex computational algorithms, especially when the integration is referring to system-based technologies, such as GIS and remote sensing. In this sense, integration may be defined as the establishment of numerical consistency across disparate digital data models and the execution of robust programming algorithms (Archibald, 1987; Brown and Fletcher, 1994; Abel *et al.*, 1994). In addition, emphasis is on computational schemata that ensure either efficient dual operability across software platforms or, preferably, the creation of a hybrid database capable of handling incongruent data at variable resolution, complexity, quality and completeness (Zhou, 1989). Under this definition, the integration of data (the beginnings of data fusion) and algorithms may be numerically