Barry Boots, Atsuyuki Okabe and Richard Thomas

# Introduction

## 1. Context

Definitions of what constitutes a *system* are legion, but arguably the most enduring is that given by Hall and Fagen (1956). Their system is a set of objects together with the relationships between these elements and their attributes. In geography, these objects are usually physical entities like towns, regions or stream links that form larger units like urban, national or drainage basin systems. The attributes of such objects are often measures of their capacity (population size, link length etc.) which serve to constrain the flows of people, information or energy between these constituent parts. At any point in time, these flows define the behaviour of the system and the purpose of their investigation is to develop an analytical capability to either reconstruct past behaviour or to anticipate future change. What makes geographical systems particularly distinctive is that their analysis usually requires the specification of relationships measuring *locational* characteristics of the objects like their degree of *spatial separation*. Typically, flows will be inhibited by such separation either through increasing travel costs or the laws of energy conservation.

Accordingly, the magnitude of any system of geographical interest may range from a few metres to thousands of kilometres. In addition, systems at large scales may nest within those at smaller geographic scales. The features considered may be physical (*natural geographical systems*), social and economic (*human geographical systems*), or both (*integrated geographical systems*). Thus, by their very nature, geographical systems are extremely complex and ever changing.

Inevitably, the representation of geographical systems depends on models, which employ various levels and degrees of abstraction, to simplify and analyze geographic reality. The particular form of abstraction chosen depends on the available data, our knowledge of the processes involved and how they operate, and the spatial extent of the area to be studied. They also depend on the objectives of the analyst so that the models may be *exploratory*, *explanatory*, or *predictive*. Further, they may consider a system at one point in time (*static model*) or explore changes in its behaviour over discrete or continuous time (*dynamic model*). Given these considerations, no single method or approach dominates geographical systems modelling. The response adopted by many modellers is to integrate appropriate concepts, procedures and techniques drawn from multiple sources. Consequently, the array of models for analyzing geographical systems and schemes for classifying them are almost as diverse and extensive as the systems themselves (Wegener, 1999). In this book, we focus



*B. Boots et al. (eds.), Modelling Geographical Systems,* 1–8.

on just two types, statistical and computational models, which are becoming increasingly important in the analysis of geographical systems.

As their name suggests, *statistical models* primarily use statistical concepts to represent the real world components and their interactions. *Computational models* employ the computer as an integral part of the modelling procedure. As such they are part of a larger body of activity referred to as geocomputation (Longley *et al.*, 1998). Computational models typically involve computationally intensive procedures such as simulation and their outputs are often highly visual and interactive in nature. In practice the two types of model are not mutually exclusive, in part, because both types have exploited recent conceptual and technical advances described below to make more efficient use of data and to stimulate new ways of exploring data. Thus, the two are best thought of as representing convenient labels for two complimentary modelling styles that may be mixed according the nature of the system being analyzed and the goals of the researcher.

One of the major recent conceptual advances has been the move within the spatial sciences towards analysis in a local context. This stems from the recognition that as well as examining regularities in system-wide behaviour (*global analysis*), it is important to search for significant, site specific variations from the global trends within the system (*local analysis*) (Fotheringham, 1997, 1999; Fotheringham and Brunsdon, 1999; Unwin and Unwin, 1998). This is particularly important for geographical systems which are likely to be inhomogeneous in terms of environmental and human conditions at most scales of analysis.

Local analysis has arisen in response to several influences. Fundamental developments in key information collection technologies have meant that large, complex, and frequently updated spatial data sets have become increasingly available. Some of these are the result of larger spatial coverage, finer spatial resolution, or both, associated with developments in automated monitoring devices such as orbiting earth satellites. Others are a product of the increasing penetration of computerization into virtually all facets of society's public and private sector administrative activities (Openshaw, 1998). Regardless of its origin, the larger the size of the data set studied, the more likely it will be heterogeneous (Unwin, 1996).

Another influence on the development of local analysis is changes in computer environments, in particular, increases in computing power and memory capacity, coupled with cheaper hardware costs. Related to this is the on-going development of more sophisticated geographical information systems (GIS) which, amonsgt other things, provide ideal environments for visualizing the multiple results of local analyses in a variety of ways.

Such developments in computing, in general, and in GIS, in particular, have also been influential elsewhere in modelling geographical systems (Fotheringham and Wegener, 2000). Advances in computing technology have made computationally intensive operations both viable and practical. Another ramification is that, conditional on data availability, analysts now have the opportunity to turn theoretical models into operational ones. The papers by Lee and Konagawa (this volume) provide examples of this tendency.

GIS were conceived as sophisticated spatial data processing and display systems and they continue to be important in this regard (Hearnshaw and Unwin, 1994). As such they provide rich environments in which modellers can apply their skills (as in Lee and Zhao and Tamura's papers in this volume). However, most GIS originally had only rudimentary analytical abilities. Much recent effort has been devoted to remedying this shortcoming. This activity includes incorporating the capability to handle effectively tasks such as formal analysis and human reasoning required to implement spatial decision support systems (see Feick and Hall, this volume). The combination of traditional and new roles for GIS has lead Sui and Goodchild (2001) to proclaim the advent of GIS as media. They suggest that GIS has joined with other mass media as a way of communicating information, especially geographical information, to the general public. An illustration of this is the VENTEN System (see Ogawa *et al.*, this volume). This view of GIS as media is also consistent with growing interest in spatial multimedia and virtual reality (Camara and Raper, 1999).

Another increasingly influential external force on the modelling of geographical systems is the rapid growth of the Internet. Not only has this opened up new possibilities in terms of data availability and storage, it has also provided an alternate platform for GIS through network GIS (Coleman, 1999). Together with other communications networks, the World-Wide Web, and other electronic "places", the Internet forms cyberspace (Dodge and Kitchin, 2000, 2001). While we have much to learn about the geography of such digital spaces, cybergeography (see Baker, Shiode, and Takeyama, this volume), it is already clear that the Internet has been responsible for a new generation of "time-space convergence" (Janelle, 1969) whereby the uneven distribution of Internet development has caused shrinkages in the time distance between specific places. There are indications that these new forms of space will have fundamental effects on social and economic behavior ranging from inter-personal communication (Takeyama, this volume) to retailing (Baker, this volume).

The various changes identified above have resulted in greater emphasis being placed on problem and application oriented approaches. Gone are the days of general, theory-led models in search of suitable applications. Today's models are much more likely to be data-driven responses to specific environmental and social problems such as natural hazards (Zhao and Tamura, this volume) and the transmission of HIV in space and time (Smith and Thomas, this volume). They are also more likely to be involved with predictions (Konagawa, this volume) and to have proactive concerns, especially when modelling outputs have obvious implications for future social or environmental policy decisions (Ballas *et al.* and Watanabe *et al.*, this volume).

## 2. CONTENTS

In this book we present 17 papers which illustrate a range of innovative ideas involved in analyzing geographical systems using statistical and computational models. These papers were selected from those presented at the sessions of the Commission on Modelling Geographical Systems at the 29th Congress of the International Geographical Union held in Seoul, Korea in August 2000. Collectively, the papers span all geographic scales, deal with both individuals and aggregates, and represent natural, human, and integrated spatial systems. Reflecting current concerns for relevance, each paper has an applied component relating to one or more contemporary issues.

The book is organized into two parts corresponding to the two types of models, statistical and computational. In turn, each part is divided into sections.[1] Part I has two sections. Section A focuses on spatial statistics and all papers in this section show how the local/global tension described above may be profitably used to facilitate integrative understanding of spatial processes operating at different scales. They also demonstrate how the emphasis in much of this work has swung away from confirmatory analyses towards exploratory ones. This is a partial reflection of the increasing size and complexity of available data sets as well as the recognition of a reduced role for classical statistical inference (Fotheringham *et al.*, 2000). Further, the techniques used in all three papers are computationally intense and would have not been possible without the recent developments in computer environments outlined above.

In the first of these, Lee shows how a statistical procedure, join-counts, originally developed to analyze static patterns at a global scale, can also be used to explore local changes in spatial processes over time. He illustrates his approach by analyzing residential development at the land parcel level for Geauga County in northeastern Ohio, USA over the past two hundred years. In a similar fashion, the second paper by Boots shows how concepts and procedures involved in identifying distinctive observations in a global data set (local measures of spatial association) can be developed into a means of evaluating polygon boundaries recorded in choropleth maps of thematic properties such as forest characteristics. In the final paper in this section Nakaya develops an existing local modelling procedure, geographically weighted regression (GWR) to produce local versions of a global spatial interaction model. These are then used to gain more detailed insight into migration flows in Japan during the latter half of 1980.

Section B is composed of papers that all combine space and time in the specification of the system but they do so at markedly different geographical scales. They all offer support to the emerging view that time need not be viewed in the traditional linear fashion. The first paper in this section, by Joh *et al.*, adopts an activity-based modelling approach in which travel is viewed as a consequence of participating in activities rather than being pursued for its own sake. Using a simulation approach, they develop a conceptualization and specification of processes by which individuals make adjustments to the repetitive components of their short-term activity schedules in response to unforeseen events. In contrast, in the second paper in this section, Mizuno explores circular and cumulative causation processes over a longer time horizon and at a larger geographic scale to examine urban agglomeration in East Asian countries. The "geographical metropolis model" he creates combines components of both economic and geographic models of urban industrial aggregates. The last paper in this section considers a continental scale. In it Smith and Thomas add a time component to the principles of spatial interaction theory to represent regional contact rates and use these to fit an epidemic model to recorded national AIDS incidence in Europe for two different scenarios of population mixing.

There are three sections in Part II. The first section contains simulation models. Although the three papers in this section span geographic scales ranging from neighbourhoods within cities, through individual cities, to nation states, they share a common concern with predicting the effects of changing inputs on the behaviour of the system under investigation. Using microsimulation modelling applied to UK Census Samples of Anonymised Records (SARs), Ballas *et al.* create a spatially disaggregated data set of attributes of individuals and households for the Leeds (UK) Metropolitan District. In turn, this micro-data is used to examine the impacts of alternative social policies upon the economic well-being of the District's residents. Watanabe *et al.*'s approach is an integrated one which simulates the diurnal climate of variously configured urban regions to examine the effects of different land use patterns on energy consumption. Konagaya also combines physical and economic conditions to create a probabilistic version of the Von Thünen-Ricardo model that permits a consideration of land use mixes. This model is used to predict the impact of increasing urbanization on the distribution of agricultural land use in China.

As noted above, most contemporary GIS packages were designed primarily as spatial data management systems and, as such, lack much of the functionality necessary for analyzing geographical systems. However, the computational capabilities of GIS software offer substantial potential for the development of such activities. The papers in Section B illustrate three novel ways in which this potential can be exploited. In Japan, pre-World War II statistical data is lacking and so Koike and Arai devise a method for estimating past population distributions using old, paper, pre-GIS era maps manipulated within a GIS environment. Zhao and Tamura take standard equations for describing physical systems and place them in a spatial context to create a spatial hydrological model. Then they combine this model with a digital elevation model and soil and vegetation databases within a GIS to estimate landslide, mudflow and flood hazards in the Sendai watershed in Japan. Hall and Fieck extend traditional, non-spatial decision analysis and model this using a GIS to provide an interactive, multi-criteria decision process for exploring the consensus and conflict surrounding tourist land development in an environmentally sensitive area in the Cayman Islands.

The final section is perhaps the most eclectic, reflecting its topic, the Internet. This is one area where scientific developments currently lag behind techno-

Springer
http://www.springer.com/978-1-4020-0821-4

Modelling Geographical Systems
Statistical and Computational Applications
Boots, B.; Okabe, A.; Thomas, R. (Eds.)
2002, X, 360 p., Hardcover
ISBN: 978-1-4020-0821-4