# Foreword

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Stan Openshaw, Professor of Geography at Leeds University, has built a reputation as a staunch advocate of computational methods for solving spatial problems. A decade ago he developed the first geographical analysis machine (GAM) to search through many alternative descriptions of patterns of human spatial interaction for new models. Other GAMs were built to search for anomalies in patterns of rare diseases such as leukemia. Stan was the foremost originator of a new field of geocomputation that promotes the use of computing to address and model complex geographic problems: there is now a center for geocomputation at Leeds, and a successful international conference series. It seems very appropriate, then, that the editors of this book have chosen to dedicate it to Stan, in recognition of his unique contribution to the invention of new computer-based methods for solving spatial problems, and of the exciting potential role of evolutionary modeling.

Evolution has populated the world with large numbers of highly successful organisms, each almost perfectly adapted to making use of the resources of its environment, and to resisting that environment's physical and biological hazards. The actual process of evolution is relatively simple, requiring only three mechanisms: one to produce significant variations in existing individuals in the next generation; one to ensure that only the most successful individuals of any generation survive; and one to preserve successful variations in future generations of individuals. If the environment is itself changing, then the process will work only if changes occur slowly in comparison to the lifetime of individuals; otherwise, it will not be possible for individuals to adapt successfully to environmental change.

Although the mechanisms are simple, with enough individuals and enough time the process will necessarily result in individuals that are almost optimally adapted to their environment. Of course the sheer scale of biological evolution is simply stunning: some 4 billion years, and numbers of individuals that can range into the trillions. Although the human race has had a mere 3 million years to evolve from its nonhuman ancestors, that is enough time for some 200,000 generations, and with 6 billion individuals now occupying the planet the potential for evolutionary adaptation is ample (although humans may now be changing their environment more rapidly than is prudent).

Many practical problems involve the search for optima against defined criteria. We humans are constantly solving such problems, as we pick routes to travel between places that minimize distance or travel time; as we design houses that provide an optimum level of comfort; or as we attempt to maximize the income we receive from investments. Many of these problems involve vast numbers of potential solutions, and it would be impossible for anyone to evaluate them all; instead, methods must be devised for solving them that cleverly exploit the structure of the problem. In the past, mathematics provided the basis for clever solutions, but only in certain circumstances; many classes of problems proved too difficult to analyze using mathematical tools. For example, the problem of finding the shortest tour through a known set of destinations—the traveling salesman problem—is known to be impossible to reduce using mathematical analysis, and consequently is very hard to solve. In principle, there are $n!/2$ possible tours through $n$ destinations, and although some possible tours can be rejected out of hand, the number of reasonable alternatives for even a modest value of $n$ is massive.

Computing power has grown enormously since the 1960s, enabling many new kinds of analysis. Evolutionary modeling exploits this increase in power, by emulating the behavior of a large population of individuals in biological systems as they go about their processes of reproduction, genetic diversification, and natural selection, with the implicit objective of optimizing themselves against the conditions that prevail in their environment. Of course it is still not possible to model the behavior of all of the billions of individuals of a species, but it is possible to reduce greatly the time taken for individuals to reach breeding age and reproduce, allowing these methods to produce useful results even with comparatively small populations.

This book is about the application of these methods of evolutionary modeling to spatial problems, or problems that involve searching for optima in geographic space. Geographic spaces tend to be enormously complex, requiring massive investment in their description and representation. For example, given a hard drive of 10 gigabytes it is possible to allocate only two words of plain language to the description of every square kilometer of the Earth's surface; and more detailed descriptions of much smaller areas typically run to terabytes. Many of the entities we design on the Earth's surface—buildings, cities, agricultural systems—are also complex. So spatial problems are particularly suited to evolutionary approaches that can harness the power of modern computers to analyze very large numbers of complex options.

The authors of this book have chosen a novel but intriguing approach, by beginning with a systematic and formal introduction to the topic, and then by inviting other contributors to write about applications. The result is a very useful compendium that will be an excellent text for specialist courses, and an important reference for researchers and users. Evolutionary modeling is still relatively unknown in the context of geographic information systems, a situation that is badly in need of correction if these systems are to live up to their claim to be indispensable for spatial decision support. This book will do much to correct that, and should encourage the builders of GISs either to offer evolutionary modeling directly, or to support its easy integration.