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Chapter IX

An Object-Oriented Approach to Managing Fuzziness in Spatially Explicit Ecological Models Coupled to a Geographic Database

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Abstract

This chapter uses a spatially explicit, individual-based ecological modeling problem to illustrate an approach to managing fuzziness in spatial databases that accommodates the use of nonfuzzy as well as fuzzy representations of geographic databases. The approach taken here uses the Extensible Component Objects for Constructing Observable Simulation Models (ECO-COSM) system loosely coupled with geographic information systems. ECO-COSM Probe objects flexibly express the contents of a spatial database within the context of an individualized fuzzy schema. It affords the ability *to transform traditional nonfuzzy spatial data into fuzzy sets that capture the uncertainty inherent in the data and model's semantic structure. The ecological modeling problem was used to illustrate how combining Probes and ProbeWrappers with Agent objects affords a flexible means of handling semantic variation and is an effective approach to utilizing heterogeneous sources of spatial data.*

Introduction

Progress in global connectivity has led to a situation where we now need to deal with more heterogeneous information consisting of a broad variety of digital spatial/geographical data and address operational sources, such as simulation models, which create new data and information. The scale of the problem has changed from just a few databases to thousands, perhaps millions, as geographical information resources. Such new resources are most often added independently to the accessible set of resources without regard to the myriad end-uses that may be applied to them (Mackay, 1999). Thus, spatially explicit information resources may be used in many different contexts without regard for the underlying uncertainties of the data, or their relationships to the semantics of the problem domain (Robinson & Frank, 1985; Burrough & Frank, 1996). Although such uncertainties in geographic databases have been recognized for decades, it would be extraordinary to have institutional databases contain anything as detailed as fuzzy membership values or other detailed measures of uncertainty attached to objects or tuples.

Geographic databases with no explicitly recorded uncertainty measures are commonly used as the basis for computationally intensive investigations of complex ecological systems. One major approach that developed over the past few decades is individual-based modeling (IBM) (Grimm, 1999; Lomnicki, 1999; Bian, 2003). It is a computational approach to modeling a system through the interaction of atomic models of each individual inhabiting the system. They provide several advances over traditional ecosystem models. Foremost among the advances is the fact that they discard the assumption that there is some average, or mean, individual that adequately represents every individual in a population. They also dispose of the assumption that significant interactions take place evenly across populations. Such models are usually spatially explicit, allowing interaction between individuals to occur over a wide range of space. Importantly, they are able to represent the biological, physiological, and behavioral distinctions seen in individuals in the real world. Because the individual is the atomic unit, the simulation is able to take spatially explicit localized interac-

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