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Fuzzy Modeling with Spatial Information for Geographic Problems

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(Editors)

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With 135 Figures

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Foreword

The capabilities of modern technology are rapidly increasing, spurred on to a large extent by the tremendous advances in communications and computing. Automated vehicles and global wireless connections are some examples of these advances. In order to take advantage of such enhanced capabilities, our need to model and manipulate our knowledge of the geophysical world, using compatible representations, is also rapidly increasing. In response to this one fundamental issue of great concern in modern geographical research is how to most effectively capture the physical world around us in systems like geographical information systems (GIS). Making this task even more challenging is the fact that uncertainty plays a pervasive role in the representation, analysis and use of geospatial information. The types of uncertainty that appear in geospatial information systems are not the just simple randomness of observation, as in weather data, but are manifested in many other forms including imprecision, incompleteness and granularization. Describing the uncertainty of the boundaries of deserts and mountains clearly require different tools than those provided by probability theory. The multiplicity of modalities of uncertainty appearing in GIS requires a variety of formalisms to model these uncertainties. In light of this it is natural that fuzzy set theory has become a topic of intensive interest in many areas of geographical research and applications

This volume, *Fuzzy Modeling with Spatial Information for Geographic Problems*, provides many stimulating examples of advances in geographical research based on approaches using fuzzy sets and related technologies. It includes chapters on diverse research topics such as spatial directions, geographical interpolation, landscape features and spatial decision systems among others. The editors, Maria Cobb, Vince Robinson and Fred Petry provide a snapshot of current topics of research and should stimulate work in this area and hopefully encourage more cross-disciplinary efforts such as demonstrated by these chapters. The papers published in this volume should be of considerable interest to a broad spectrum of researchers in the fuzzy set and GIS areas as well as those engineers who make use of geospatial information in their applications and systems.

Ronald R. Yager
New York, NY USA
August 25, 2004

Preface

This volume, the companion to *Flexible Querying and Reasoning in Spatio-Temporal Databases* edited by Rita De Caluwe, Guy De Tre, and Gloria Bordogna, focuses on advances in research on approaches to incorporating explicit handling of uncertainty, especially by fuzzy sets, to address geographic problems. Over the past several years interest in the use of fuzzy approaches has grown across a broad spectrum of fields that use spatial information to address geographic problems.

The reasoning about geographic information representing regions, relations, and/or fields is fundamental to any progress in the application of fuzzy sets to modeling geographical problems. There are several papers in this volume that advance our understanding of these fundamental issues. Hans Guesgen builds on his previous work that introduces fuzzy sets into the artificial intelligence community's RCC theory. His results suggest that the formalism developed by converting RCC8 relations into fuzzy sets and applying a fuzzy RCC8 algorithm is robust under uncertainty. Pascal Matsakis and Dennis Nikitenko focus on issues of modeling fuzzy spatial relations. They introduce the Force Histogram (F-histogram) and proceed to illustrate that the F-histogram is a valuable tool for extracting directional and topological relationship information from two spatial objects exploiting a fuzzification of Allen relations.

Much of the research on fuzzy modeling applied to geographical problems is based on a geographic information system that represents information as layers and uses a field based approach to processing the spatially explicit data. Jörg Verstraete and colleagues present their exploration of two types of field based methods for the modeling of fuzzy spatial data. They discuss the extended triangulated irregular networks and extended bitmap models with respect to fuzzy membership values, fuzzy numbers, operations, type-2 fuzzy sets, and possibilistic truth values. Thus, it is an in depth exploration of fuzzy extensions to two very important, fundamental models of geographic information.

Sungsoon Hwang and Jean-Claude Thill model localities as fuzzy regions represented as eggs in the egg-yolk model of spatial representation. Their study illustrates a real world problem domain where fuzzy regions and linguistic variables are shown to be useful in addressing the problem of pinpointing the location of a traffic accident given limited and imprecise (*e.g.* linguistic) information. In the case of emergency dispatch operations, the outcome of this process could have profound consequences.

One of the most common approaches to fuzzy modeling of spatial data for geographical problem solving consists of constructing a fuzzy classification. The fuzzy k-means algorithm has a long history of being applied to geographical problems.

Zhijan Liu and Roy George propose an extension to the fuzzy k-means algorithm to account for both spatial and temporal data. They demonstrate its utility in another important problem area of geographical data analysis, namely data mining, by showing that it is able to identify interesting phenomena with a large weather data set. Cidália Fonte and Weldon Lodwick identify four different sources of fuzziness in their two phase classification procedure. For each source of fuzziness, a method to compute the membership grades for fuzzy geographical entities is presented, based on semantic interpretation of the grades of membership. These semantic interpretations are the likelihood view, the random set view and the similarity view. They show that these semantic interpretations are suitable for construction of fuzzy geographical entities.

Although spatial interpolation is a commonly used technique in geographical analysis, the use of fuzzy spatial interpolation is not yet widespread, especially when incorporating temporal dynamics. Suzana Dragićević presents the potential of using fuzzy set theory to deal with imperfect geographic data and entities when applying GIS based spatial and spatio-temporal interpolation.

Susan Kratochwill and Josef Benedikt present the argument that the uncertainty inherent in geographic information systems is due to the semantics of categorization using linguistic symbols in a process of communication. They go on to present the Talking Space platform for mapping spatial knowledge with uncertainty. Ferdinando Di Martino and colleagues show how the FUZZY-SRA software tool is used to evaluate the reliability of environmental data for the island of Procida.

Landscape features have long been recognized as being inherently fuzzy concepts whose inherent fuzziness has historically been difficult to represent in a manner that is flexible enough to be useful in any but a single problem domain operating at a single scale. Xun Shi and colleagues present a similarity-based method for deriving fuzzy representation of terrain features such as ridges (broad vs narrow), headwaters, and “knobs” that is computationally efficient, effective and flexible. Peter Fisher and colleagues explain the effect that scale has on how landscape features can be modeled using fuzzy sets. This paper represents one of the first to explicitly model landscape morphometry at multiple scales using fuzzy sets.

With the rapid escalation in computational technology and digital geographic data fuzzy modeling of spatial data has become increasingly important in those applications where decision making is of utmost importance. Frank Witlox and Ben Derudder elaborate on fuzzy decision tables as an important addition to qualitative modeling. They show it is possible to explicate the imprecision involved in the decision making process through use of fuzzy decision tables and discuss possible limitations, especially in relation to the use of fuzzy knowledge based systems. Ashley Morris and Piotr Jankowski present the FOOSBALL system that allows for multiple criteria fuzzy queries over an object oriented spatial database. Vince Robinson and Phil Graniero present a computational framework and methodology for modeling small mammals as mobile fuzzy agents making decisions during their dispersal process.

This book has the two aims. One is to stimulate further research in both the theory and application of fuzzy sets to spatial information management and geographic problem solving. The other is to show the advances in research that have matured to the point that we find fuzzy modeling being used by geoscientists, computer scientists, geographers, ecologists, engineers, and others.

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