hierarchical modeling and analysis for spatial data

Hierarchical Modeling and Analysis for Spatial Data: Unlocking Geographic Patterns

Introduction:

Are you grappling with complex spatial datasets that exhibit nested structures? Do you need to uncover hidden relationships within geographically clustered data, accounting for both local variations and broader regional trends? Then you need to understand hierarchical modeling and analysis. This comprehensive guide dives deep into this powerful statistical technique, providing a clear and practical understanding of its principles, applications, and benefits for analyzing spatial data. We'll explore different model types, implementation strategies, and common challenges, equipping you with the knowledge to effectively leverage hierarchical modeling in your own spatial analysis projects. Prepare to unlock the intricacies of your geographical data and reveal meaningful insights you might have otherwise missed.

1. Understanding Spatial Data and its Hierarchical Nature:

Spatial data, by its very nature, often exhibits hierarchical structures. Think of census data nested within counties, counties within states, and states within a nation. Similarly, ecological data might involve observations within plots, plots within fields, and fields within regions. This nesting creates dependencies between observations at different levels, violating the assumptions of many standard statistical models. Ignoring these hierarchical structures can lead to inaccurate inferences and biased results. Hierarchical modeling explicitly accounts for these dependencies, providing more robust and realistic analyses. We'll explore various examples of hierarchical structures in common spatial datasets, illustrating the importance of considering these nested relationships.

2. The Fundamentals of Hierarchical Modeling:

Hierarchical models, also known as multilevel models or mixed-effects models, employ a flexible framework that allows for the simultaneous analysis of data at multiple levels. This is achieved by incorporating random effects that capture the variation within and between levels of the hierarchy. These random effects are assumed to be drawn from a probability distribution,

allowing for the estimation of both fixed effects (representing overall trends) and random effects (representing level-specific deviations from those trends). We will discuss the key components of hierarchical models: fixed effects, random effects, and their respective interpretations. We'll use clear examples to demonstrate how these components work together.

3. Different Types of Hierarchical Models for Spatial Data:

Several types of hierarchical models are suited for different spatial data structures and research questions. We'll explore some of the most commonly used, including:

Linear Mixed-Effects Models (LMMs): These are suitable for continuous response variables and are widely used in spatial analysis to model relationships between covariates and outcomes while accounting for spatial autocorrelation. We'll delve into how to specify the random effects structure to properly model spatial dependencies.

Generalized Linear Mixed-Effects Models (GLMMs): These extend LMMs to handle non-normal response variables, such as binary (presence/absence) or count data, which are frequently encountered in spatial ecology and epidemiology.

Spatial Hierarchical Bayesian Models: These models offer greater flexibility and allow for the incorporation of prior information, making them particularly useful when dealing with limited data or complex spatial dependencies. We will discuss Markov Chain Monte Carlo (MCMC) methods, a common approach for estimating these models.

4. Implementing Hierarchical Models: Software and Techniques:

The implementation of hierarchical models involves specialized statistical software. We'll discuss popular options such as:

R: With packages like `lme4`, `nlme`, and `rstanarm`, R provides a powerful and versatile environment for fitting hierarchical models. We'll provide code snippets to illustrate the implementation process.

SAS: SAS offers PROC MIXED and other procedures specifically designed for fitting mixed-effects models.

WinBUGS/OpenBUGS/JAGS: These software packages are particularly suitable for fitting Bayesian hierarchical models. We will briefly explain the concepts of MCMC sampling.

5. Model Diagnostics and Interpretation:

Proper model diagnostics are crucial for ensuring the reliability of the results obtained from hierarchical models. We'll discuss essential steps such as:

Assessing model fit: We'll explain methods for checking the adequacy of the model in representing the data, including residual analysis and goodness-of-fit tests.

Interpreting fixed and random effects: We will delve into the interpretation of both fixed effects (population-level effects) and random effects (level-specific deviations), highlighting the importance of distinguishing between these components.

Quantifying uncertainty: We will discuss how to quantify the uncertainty associated with model parameters and predictions using confidence intervals or credible intervals (in the Bayesian context).

6. Advanced Topics and Extensions:

Beyond the basics, hierarchical modeling offers numerous advanced possibilities:

Spatial autocorrelation: We will discuss strategies for accounting for spatial autocorrelation in the residuals, including using spatially correlated random effects or incorporating spatial weights matrices.

Model selection: We'll touch upon methods for selecting the best model structure, considering the trade-off between model complexity and fit.

Dealing with missing data: We will briefly discuss strategies for handling missing data in hierarchical models.

7. Real-World Applications and Case Studies:

To solidify your understanding, we'll present real-world applications of hierarchical modeling in diverse fields, including:

Ecology: Modeling species distribution in relation to environmental covariates while accounting for spatial autocorrelation.

Public health: Analyzing disease incidence rates across different geographical regions, considering variations at multiple levels.

Economics: Modeling economic indicators across different geographical units, considering regional variations.

8. Conclusion: The Power and Versatility of Hierarchical Modeling for Spatial Data:

Hierarchical modeling provides a powerful and flexible framework for analyzing complex spatial datasets with nested structures. By explicitly accounting for dependencies between observations at different levels, it allows for more accurate inferences and a deeper understanding of spatial patterns. This guide has provided a foundational understanding of the principles, techniques, and applications of this valuable statistical approach. Mastering hierarchical modeling empowers researchers to extract meaningful insights from their spatial data, leading to more informed decision-making and a more comprehensive understanding of the geographic phenomena under investigation.

Book Outline: "Mastering Hierarchical Modeling for Spatial Data"

I. Introduction:
What is Hierarchical Modeling?
Why Use Hierarchical Models for Spatial Data?
Types of Spatial Data and Their Hierarchical Structure
Overview of the Book

II. Foundations of Hierarchical Modeling:
Statistical Modeling Basics
Linear Mixed-Effects Models (LMMs)
Generalized Linear Mixed-Effects Models (GLMMs)
Bayesian Hierarchical Models
Model Specification and Interpretation

III. Implementing Hierarchical Models:
Software Packages (R, SAS, WinBUGS/OpenBUGS/JAGS)
Data Preparation and Preprocessing
Model Fitting and Diagnostics
Model Comparison and Selection

IV. Advanced Topics and Extensions:
Spatial Autocorrelation and Spatial Random Effects
Handling Missing Data in Hierarchical Models
Model Sensitivity Analysis and Robustness Checks

V. Case Studies and Applications:
Applications in Ecology
Applications in Public Health
Applications in Economics and other fields

VI. Conclusion:
Summary of Key Concepts

Future Directions in Hierarchical Modeling for Spatial Data

Article Explaining Each Point of the Outline:

Each section of the book outline would be expanded into a detailed chapter, covering the theoretical foundations, practical implementation, and real-world applications of the specific topic. For instance, the chapter on "Linear Mixed-Effects Models (LMMs)" would provide a thorough explanation of LMMs' mathematical formulation, parameter estimation techniques, and interpretation of results. The chapter on "Implementing Hierarchical Models" would include detailed code examples in R, SAS, and Bayesian software packages. Each chapter would be illustrated with examples and case studies to solidify the reader's understanding.

9 Unique FAQs:

1. What is the difference between a hierarchical model and a standard regression model? Hierarchical models explicitly account for the nested structure of data, incorporating random effects to model variation at multiple levels, while standard regression models assume independence between observations.

1. How do I choose the appropriate hierarchical model for my spatial data? The choice depends on the nature of your response variable (continuous, binary, count, etc.) and the specific research question.

1. What are the advantages of using Bayesian hierarchical models over frequentist approaches? Bayesian models allow for the incorporation of prior information, provide a natural framework for handling uncertainty, and often offer greater flexibility in model specification.

1. How do I deal with spatial autocorrelation in my hierarchical model? Several techniques can be employed, including incorporating spatially correlated random effects or using spatial weights matrices.

1. What are the common challenges in fitting and interpreting hierarchical models? Challenges include model convergence issues (in Bayesian models), dealing with complex random effects structures, and correctly

interpreting random effects estimates.

1. How can I assess the goodness of fit of my hierarchical model? Various methods can be used, including residual analysis, likelihood ratio tests, and information criteria (AIC, BIC).

1. What software packages are best suited for fitting hierarchical models? R, SAS, and Bayesian software such as WinBUGS, OpenBUGS, and JAGS are popular choices.

1. What are some real-world examples of hierarchical models applied to spatial data? Examples include disease mapping, species distribution modeling, and environmental impact assessment.

1. How can I interpret the random effects estimates in a hierarchical model? Random effects represent the deviations of individual units (e.g., counties, plots) from the overall population-level effects.

9 Related Articles:

1. Spatial Autocorrelation and its Implications for Spatial Statistical Modeling: Discusses the concept of spatial autocorrelation and its impact on statistical inferences.

1. Introduction to Geostatistics: Explores the principles and methods of geostatistics, a branch of spatial statistics focusing on continuous spatial phenomena.

1. Bayesian Methods for Spatial Data Analysis: Covers Bayesian approaches to analyzing spatial data, including Markov Chain Monte Carlo (MCMC) methods.

1. Point Pattern Analysis: Focuses on the analysis of point patterns in space, such as the locations of trees in a forest or disease cases in a region.

1. Kriging and Spatial Interpolation: Explains kriging, a powerful geostatistical technique for interpolating spatial data.

1. Generalized Additive Models (GAMs) for Spatial Data: Introduces GAMs as a flexible approach for modeling non-linear relationships in spatial data.

1. Spatial Regression Models: Explores various spatial regression models, including spatial lag and spatial error models.

1. Handling Missing Data in Spatial Analysis: Discusses strategies for dealing with missing data in spatial datasets.

1. Model Selection in Spatial Statistics: Covers various model selection criteria and techniques for choosing the best model for spatial data analysis.

hierarchical modeling and analysis for spatial data: Hierarchical Modeling and Analysis for Spatial Data Sudipto Banerjee, Bradley P. Carlin, Alan E. Gelfand, 2003-12-17 Among the many uses of hierarchical modeling, their application to the statistical analysis of spatial and spatio-temporal data from areas such as epidemiology And environmental science has proven particularly fruitful. Yet to date, the few books that address the subject have been either too narrowly focused on specific aspects of spatial analysis,

hierarchical modeling and analysis for spatial data: *Hierarchical Modeling and Analysis for Spatial Data, Second Edition* Sudipto Banerjee, Bradley P. Carlin, Alan E. Gelfand, 2014-09-12 Keep Up to Date with the Evolving Landscape of Space and Space-Time Data Analysis and Modeling Since the publication of the first edition, the statistical landscape has substantially changed for analyzing space and space-time data. More than twice the size of its predecessor, Hierarchical Modeling and

Analysis for Spatial Data, Second Edition reflects the major growth in spatial statistics as both a research area and an area of application. New to the Second Edition New chapter on spatial point patterns developed primarily from a modeling perspective New chapter on big data that shows how the predictive process handles reasonably large datasets New chapter on spatial and spatiotemporal gradient modeling that incorporates recent developments in spatial boundary analysis and wombling New chapter on the theoretical aspects of geostatistical (point-referenced) modeling Greatly expanded chapters on methods for multivariate and spatiotemporal modeling New special topics sections on data fusion/assimilation and spatial analysis for data on extremes Double the number of exercises Many more color figures integrated throughout the text Updated computational aspects, including the latest version of WinBUGS, the new flexible spBayes software, and assorted R packages The Only Comprehensive Treatment of the Theory, Methods, and Software This second edition continues to provide a complete treatment of the theory, methods, and application of hierarchical modeling for spatial and spatiotemporal data. It tackles current challenges in handling this type of data, with increased emphasis on observational data, big data, and the upsurge of associated software tools. The authors also explore important application domains, including environmental science, forestry, public health, and real estate.

hierarchical modeling and analysis for spatial data: Hierarchical Modeling and Analysis for Spatial Data Sudipto Banerjee, Bradley P. Carlin, Alan E. Gelfand, 2004-06-02 Among the many uses of hierarchical modeling, their application to the statistical analysis of spatial and spatio-temporal data from areas such as epidemiology And environmental science has proven particularly fruitful. Yet to date, the few books that address the subject have been either too narrowly focused on specific aspects of spatial analysis, or written at a level often inaccessible to those lacking a strong background in mathematical statistics. Hierarchical Modeling and Analysis for Spatial Data is the first accessible, self-contained treatment of hierarchical methods, modeling, and data analysis for spatial and spatio-temporal data. Starting with overviews of the types of spatial data, the data analysis tools appropriate for each, and a brief review of the Bayesian approach to statistics, the authors discuss hierarchical modeling for univariate spatial response data, including Bayesian kriging and lattice (areal data) modeling. They then consider the problem of spatially misaligned data, methods for handling multivariate spatial responses, spatio-temporal models, and spatial survival models. The final chapter explores a variety of special topics, including spatially varying coefficient models. This book provides clear explanations, plentiful illustrations --some in full color--a variety of homework problems, and tutorials and worked examples using some of the field's most popular software packages.. Written by a team of leaders in the field, it will undoubtedly remain the primary textbook and reference on the subject for years to come.

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primary textbook and reference on the subject for years to come.

hierarchical modeling and analysis for spatial data: *Hierarchical Modeling and Inference in Ecology* J. Andrew Royle, Robert M. Dorazio, 2008-10-15 A guide to data collection, modeling and inference strategies for biological survey data using Bayesian and classical statistical methods.This book describes a general and flexible framework for modeling and inference in ecological systems based on hierarchical models, with a strict focus on the use of probability models and parametric inference. Hierarchical models represent a paradigm shift in the application of statistics to ecological inference problems because they combine explicit models of ecological system structure or dynamics with models of how ecological systems are observed. The principles of hierarchical modeling are developed and applied to problems in population, metapopulation, community, and metacommunity systems. The book provides the first synthetic treatment of many recent methodological advances in ecological modeling and unifies disparate methods and procedures.The authors apply principles of hierarchical modeling to ecological problems, including * occurrence or occupancy models for estimating species distribution* abundance models based on many sampling protocols, including distance sampling* capture-recapture models with individual effects* spatial capture-recapture models based on camera trapping and related methods* population and metapopulation dynamic models* models of biodiversity, community structure and dynamics - Wide variety of examples involving many taxa (birds, amphibians, mammals, insects, plants) - Development of classical, likelihood-based procedures for inference, as well as Bayesian methods of analysis - Detailed explanations describing the implementation of hierarchical models using freely available software such as R and WinBUGS - Computing support in technical appendices in an online companion web site

hierarchical modeling and analysis for spatial data: Applied Spatial Statistics for Public Health Data Lance A. Waller, Carol A. Gotway, 2004-07-29 While mapped data provide a common ground for discussions between the public, the media, regulatory agencies, and public health researchers, the analysis of spatially referenced data has experienced a phenomenal growth over the last two decades, thanks in part to the development of geographical information systems (GISs). This is the first thorough overview to integrate spatial statistics with data management and the display capabilities of GIS. It describes methods for assessing the likelihood of observed patterns and quantifying the link between exposures and outcomes in spatially correlated data. This introductory text is designed to serve as both an introduction for the novice and a reference for practitioners in the field Requires only minimal background in public health and only some knowledge of statistics through multiple regression Touches upon some advanced topics, such as random effects, hierarchical models and spatial point processes, but does not require prior exposure Includes lavish use of figures/illustrations throughout the volume as well as analyses of several data sets (in the form of data breaks) Exercises based on data analyses reinforce concepts

hierarchical modeling and analysis for spatial data: Data Analysis Using Regression and Multilevel/Hierarchical Models Andrew Gelman, Jennifer Hill, 2007 This book, first published in 2007, is for the applied researcher performing data analysis using linear and nonlinear regression and multilevel models.

hierarchical modeling and analysis for spatial data: Spatial Modeling in GIS and R for Earth and Environmental Sciences Hamid Reza Pourghasemi, Candan Gokceoglu, 2019-01-18 Spatial Modeling in GIS and R for Earth and Environmental Sciences offers an integrated approach to spatial modelling using both GIS and R. Given the importance of Geographical Information Systems and geostatistics across a variety of applications in Earth and Environmental Science, a clear link between GIS and open source software is essential for the study of spatial objects or phenomena that occur in the real world and facilitate problem-solving. Organized into clear sections on applications and using case studies, the book helps researchers to more quickly understand GIS data and formulate more complex conclusions. The book is the first reference to provide methods and applications for combining the use of R and GIS in modeling spatial processes. It is an essential tool for students and researchers in earth and environmental science, especially those looking to

better utilize GIS and spatial modeling. - Offers a clear, interdisciplinary guide to serve researchers in a variety of fields, including hazards, land surveying, remote sensing, cartography, geophysics, geology, natural resources, environment and geography - Provides an overview, methods and case studies for each application - Expresses concepts and methods at an appropriate level for both students and new users to learn by example

hierarchical modeling and analysis for spatial data: *Spatial and Spatio-temporal Bayesian Models with R - INLA* Marta Blangiardo, Michela Cameletti, 2015-06-02 Spatial and Spatio-Temporal Bayesian Models with R-INLA provides a much needed, practically oriented & innovative presentation of the combination of Bayesian methodology and spatial statistics. The authors combine an introduction to Bayesian theory and methodology with a focus on the spatial and spatio-temporal models used within the Bayesian framework and a series of practical examples which allow the reader to link the statistical theory presented to real data problems. The numerous examples from the fields of epidemiology, biostatistics and social science all are coded in the R package R-INLA, which has proven to be a valid alternative to the commonly used Markov Chain Monte Carlo simulations

hierarchical modeling and analysis for spatial data: *Regression Modelling wih Spatial and Spatial-Temporal Data* Robert P. Haining, Guangquan Li, 2020-01-27 Modelling Spatial and Spatial-Temporal Data: A Bayesian Approach is aimed at statisticians and quantitative social, economic and public health students and researchers who work with spatial and spatial-temporal data. It assumes a grounding in statistical theory up to the standard linear regression model. The book compares both hierarchical and spatial econometric modelling, providing both a reference and a teaching text with exercises in each chapter. The book provides a fully Bayesian, self-contained, treatment of the underlying statistical theory, with chapters dedicated to substantive applications. The book includes WinBUGS code and R code and all datasets are available online. Part I covers fundamental issues arising when modelling spatial and spatial-temporal data. Part II focuses on modelling cross-sectional spatial data and begins by describing exploratory methods that help guide the modelling process. There are then two theoretical chapters on Bayesian models and a chapter of applications. Two chapters follow on spatial econometric modelling, one describing different models, the other substantive applications. Part III discusses modelling spatial-temporal data, first introducing models for time series data. Exploratory methods for detecting different types of space-time interaction are presented followed by two chapters on the theory of space-time separable (without space-time interaction) and inseparable (with space-time interaction) models. An applications chapter includes: the evaluation of a policy intervention; analysing the temporal dynamics of crime hotspots; chronic disease surveillance; and testing for evidence of spatial spillovers in the spread of an infectious disease. A final chapter suggests some future directions and challenges.

hierarchical modeling and analysis for spatial data: Spatial Data Analysis Robert P. Haining, 2003-04-17 Spatial Data Analysis: Theory and Practice, first published in 2003, provides a broad ranging treatment of the field of spatial data analysis. It begins with an overview of spatial data analysis and the importance of location (place, context and space) in scientific and policy related research. Covering fundamental problems concerning how attributes in geographical space are represented to the latest methods of exploratory spatial data analysis and spatial modeling, it is designed to take the reader through the key areas that underpin the analysis of spatial data, providing a platform from which to view and critically appreciate many of the key areas of the field. Parts of the text are accessible to undergraduate and master's level students, but it also contains sufficient challenging material that it will be of interest to geographers, social and economic scientists, environmental scientists and statisticians, whose research takes them into the area of spatial analysis.

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Abundance, Species Richness offers a new synthesis of the state-of-the-art of hierarchical models for plant and animal distribution, abundance, and community characteristics such as species richness using data collected in metapopulation designs. These types of data are extremely widespread in ecology and its applications in such areas as biodiversity monitoring and fisheries and wildlife management. This first volume explains static models/procedures in the context of hierarchical models that collectively represent a unified approach to ecological research, taking the reader from design, through data collection, and into analyses using a very powerful class of models. Applied Hierarchical Modeling in Ecology, Volume 1 serves as an indispensable manual for practicing field biologists, and as a graduate-level text for students in ecology, conservation biology, fisheries/wildlife management, and related fields. - Provides a synthesis of important classes of models about distribution, abundance, and species richness while accommodating imperfect detection - Presents models and methods for identifying unmarked individuals and species - Written in a step-by-step approach accessible to non-statisticians and provides fully worked examples that serve as a template for readers' analyses - Includes companion website containing data sets, code, solutions to exercises, and further information

hierarchical modeling and analysis for spatial data: Spatio-Temporal Statistics with R Christopher K. Wikle, Andrew Zammit-Mangion, Noel Cressie, 2019-02-18 The world is becoming increasingly complex, with larger quantities of data available to be analyzed. It so happens that much of these big data that are available are spatio-temporal in nature, meaning that they can be indexed by their spatial locations and time stamps. Spatio-Temporal Statistics with R provides an accessible introduction to statistical analysis of spatio-temporal data, with hands-on applications of the statistical methods using R Labs found at the end of each chapter. The book: Gives a step-by-step approach to analyzing spatio-temporal data, starting with visualization, then statistical modelling, with an emphasis on hierarchical statistical models and basis function expansions, and finishing with model evaluation Provides a gradual entry to the methodological aspects of spatio-temporal statistics Provides broad coverage of using R as well as R Tips throughout. Features detailed examples and applications in end-of-chapter Labs Features Technical Notes throughout to provide additional technical detail where relevant Supplemented by a website featuring the associated R package, data, reviews, errata, a discussion forum, and more The book fills a void in the literature and available software, providing a bridge for students and researchers alike who wish to learn the basics of spatio-temporal statistics. It is written in an informal style and functions as a down-to-earth introduction to the subject. Any reader familiar with calculus-based probability and statistics, and who is comfortable with basic matrix-algebra representations of statistical models, would find this book easy to follow. The goal is to give as many people as possible the tools and confidence to analyze spatio-temporal data.

hierarchical modeling and analysis for spatial data: *Handbook of Spatial Statistics* Alan E. Gelfand, Peter Diggle, Peter Guttorp, Montserrat Fuentes, 2010-03-19 Assembling a collection of very prominent researchers in the field, the Handbook of Spatial Statistics presents a comprehensive treatment of both classical and state-of-the-art aspects of this maturing area. It takes a unified, integrated approach to the material, providing cross-references among chapters.The handbook begins with a historical intro

hierarchical modeling and analysis for spatial data: Theory of Spatial Statistics M.N.M. van Lieshout, 2019-03-19 Theory of Spatial Statistics: A Concise Introduction presents the most important models used in spatial statistics, including random fields and point processes, from a rigorous mathematical point of view and shows how to carry out statistical inference. It contains full proofs, real-life examples and theoretical exercises. Solutions to the latter are available in an appendix. Assuming maturity in probability and statistics, these concise lecture notes are self-contained and cover enough material for a semester course. They may also serve as a reference book for researchers. Features * Presents the mathematical foundations of spatial statistics. * Contains worked examples from mining, disease mapping, forestry, soil and environmental science, and criminology. * Gives pointers to the literature to facilitate further study. * Provides example

code in R to encourage the student to experiment. * Offers exercises and their solutions to test and deepen understanding. The book is suitable for postgraduate and advanced undergraduate students in mathematics and statistics.

hierarchical modeling and analysis for spatial data: A Student's Guide to Bayesian Statistics Ben Lambert, 2018-04-20 Without sacrificing technical integrity for the sake of simplicity, the author draws upon accessible, student-friendly language to provide approachable instruction perfectly aimed at statistics and Bayesian newcomers.

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hierarchical modeling and analysis for spatial data: Applied Spatial Data Analysis with R Roger S. Bivand, Edzer Pebesma, Virgilio Gómez-Rubio, 2013-06-21 Applied Spatial Data Analysis with R, second edition, is divided into two basic parts, the first presenting R packages, functions, classes and methods for handling spatial data. This part is of interest to users who need to access and visualise spatial data. Data import and export for many file formats for spatial data are covered in detail, as is the interface between R and the open source GRASS GIS and the handling of spatio-temporal data. The second part showcases more specialised kinds of spatial data analysis, including spatial point pattern analysis, interpolation and geostatistics, areal data analysis and disease mapping. The coverage of methods of spatial data analysis ranges from standard techniques to new developments, and the examples used are largely taken from the spatial statistics literature. All the examples can be run using R contributed packages available from the CRAN website, with code and additional data sets from the book's own website. Compared to the first edition, the second edition covers the more systematic approach towards handling spatial data in R, as well as a number of important and widely used CRAN packages that have appeared since the first edition. This book will be of interest to researchers who intend to use R to handle, visualise, and analyse spatial data. It will also be of interest to spatial data analysts who do not use R, but who are interested in practical aspects of implementing software for spatial data analysis. It is a suitable companion book for introductory spatial statistics courses and for applied methods courses in a wide range of subjects using spatial data, including human and physical geography, geographical information science and geoinformatics, the environmental sciences, ecology, public health and disease control, economics, public administration and political science. The book has a website where complete code examples, data sets, and other support material may be found: http://www.asdar-book.org. The authors have taken part in writing and maintaining software for spatial data handling and analysis with R in concert since 2003.

hierarchical modeling and analysis for spatial data: Using R for Bayesian Spatial and Spatio-Temporal Health Modeling Andrew B. Lawson, 2021-04-28 Progressively more and more attention has been paid to how location affects health outcomes. The area of disease mapping focusses on these problems, and the Bayesian paradigm has a major role to play in the understanding of the complex interplay of context and individual predisposition in such studies of disease. Using R for Bayesian Spatial and Spatio-Temporal Health Modeling provides a major

resource for those interested in applying Bayesian methodology in small area health data studies. Features: Review of R graphics relevant to spatial health data Overview of Bayesian methods and Bayesian hierarchical modeling as applied to spatial data Bayesian Computation and goodness-of-fit Review of basic Bayesian disease mapping models Spatio-temporal modeling with MCMC and INLA Special topics include multivariate models, survival analysis, missing data, measurement error, variable selection, individual event modeling, and infectious disease modeling Software for fitting models based on BRugs, Nimble, CARBayes and INLA Provides code relevant to fitting all examples throughout the book at a supplementary website The book fills a void in the literature and available software, providing a crucial link for students and professionals alike to engage in the analysis of spatial and spatio-temporal health data from a Bayesian perspective using R. The book emphasizes the use of MCMC via Nimble, BRugs, and CARBAyes, but also includes INLA for comparative purposes. In addition, a wide range of packages useful in the analysis of geo-referenced spatial data are employed and code is provided. It will likely become a key reference for researchers and students from biostatistics, epidemiology, public health, and environmental science.

hierarchical modeling and analysis for spatial data: Statistical Methods for Spatial Data Analysis Oliver Schabenberger, Carol A. Gotway, 2004-12-20 Understanding spatial statistics requires tools from applied and mathematical statistics, linear model theory, regression, time series, and stochastic processes. It also requires a mindset that focuses on the unique characteristics of spatial data and the development of specialized analytical tools designed explicitly for spatial data analysis. Statistical Methods for Spatial Data Analysis answers the demand for a text that incorporates all of these factors by presenting a balanced exposition that explores both the theoretical foundations of the field of spatial statistics as well as practical methods for the analysis of spatial data. This book is a comprehensive and illustrative treatment of basic statistical theory and methods for spatial data analysis, employing a model-based and frequentist approach that emphasizes the spatial domain. It introduces essential tools and approaches including: measures of autocorrelation and their role in data analysis; the background and theoretical framework supporting random fields; the analysis of mapped spatial point patterns; estimation and modeling of the covariance function and semivariogram; a comprehensive treatment of spatial analysis in the spectral domain; and spatial prediction and kriging. The volume also delivers a thorough analysis of spatial regression, providing a detailed development of linear models with uncorrelated errors, linear models with spatially-correlated errors and generalized linear mixed models for spatial data. It succinctly discusses Bayesian hierarchical models and concludes with reviews on simulating random fields, non-stationary covariance, and spatio-temporal processes. Additional material on the CRC Press website supplements the content of this book. The site provides data sets used as examples in the text, software code that can be used to implement many of the principal methods described and illustrated, and updates to the text itself.

hierarchical modeling and analysis for spatial data: Spatial Point Patterns Adrian Baddeley, Ege Rubak, Rolf Turner, 2015-11-11 Modern Statistical Methodology and Software for Analyzing Spatial Point PatternsSpatial Point Patterns: Methodology and Applications with R shows scientific researchers and applied statisticians from a wide range of fields how to analyze their spatial point pattern data. Making the techniques accessible to non-mathematicians, the authors draw on th

hierarchical modeling and analysis for spatial data: Spatial Analysis and Modeling in Geographical Transformation Process Yuji Murayama, Rajesh Bahadur Thapa, 2011-02-26 Currently, spatial analysis is becoming more important than ever because enormous volumes of spatial data are available from different sources, such as GPS, Remote Sensing, and others. This book deals with spatial analysis and modelling. It provides a comprehensive discussion of spatial analysis, methods, and approaches related to human settlements and associated environment. Key contributions with empirical case studies from Iran, Philippines, Vietnam, Thailand, Nepal, and Japan that apply spatial analysis including autocorrelation, fuzzy, voronoi, cellular automata, analytic hierarchy process, artificial neural network, spatial metrics, spatial statistics, regression, and

remote sensing mapping techniques are compiled comprehensively. The core value of this book is a wide variety of results with state of the art discussion including empirical case studies. It provides a milestone reference to students, researchers, planners, and other practitioners dealing the spatial problems on urban and regional issues. We are pleased to announce that this book has been presented with the 2011 publishing award from the GIS Association of Japan. We would like to congratulate the authors!

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presentation of spatio-temporal processes, bridging classic ideas with modern hierarchical statistical modeling concepts and the latest computational methods Noel Cressie and Christopher K. Wikle, are also winners of the 2011 PROSE Award in the Mathematics category, for the book “Statistics for Spatio-Temporal Data” (2011), published by John Wiley and Sons. (The PROSE awards, for Professional and Scholarly Excellence, are given by the Association of American Publishers, the national trade association of the US book publishing industry.) Statistics for Spatio-Temporal Data has now been reprinted with small corrections to the text and the bibliography. The overall content and pagination of the new printing remains the same; the difference comes in the form of corrections to typographical errors, editing of incomplete and missing references, and some updated spatio-temporal interpretations. From understanding environmental processes and climate trends to developing new technologies for mapping public-health data and the spread of invasive-species, there is a high demand for statistical analyses of data that take spatial, temporal, and spatio-temporal information into account. Statistics for Spatio-Temporal Data presents a systematic approach to key quantitative techniques that incorporate the latest advances in statistical computing as well as hierarchical, particularly Bayesian, statistical modeling, with an emphasis on dynamical spatio-temporal models. Cressie and Wikle supply a unique presentation that incorporates ideas from the areas of time series and spatial statistics as well as stochastic processes. Beginning with separate treatments of temporal data and spatial data, the book combines these concepts to discuss spatio-temporal statistical methods for understanding complex processes. Topics of coverage include: Exploratory methods for spatio-temporal data, including visualization, spectral analysis, empirical orthogonal function analysis, and LISAs Spatio-temporal covariance functions, spatio-temporal kriging, and time series of spatial processes Development of hierarchical dynamical spatio-temporal models (DSTMs), with discussion of linear and nonlinear DSTMs and computational algorithms for their implementation Quantifying and exploring spatio-temporal variability in scientific applications, including case studies based on real-world environmental data Throughout the book, interesting applications demonstrate the relevance of the presented concepts. Vivid, full-color graphics emphasize the visual nature of the topic, and a related FTP site contains supplementary material. Statistics for Spatio-Temporal Data is an excellent book for a graduate-level course on spatio-temporal statistics. It is also a valuable reference for researchers and practitioners in the fields of applied mathematics, engineering, and the environmental and health sciences.

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