

# Preface

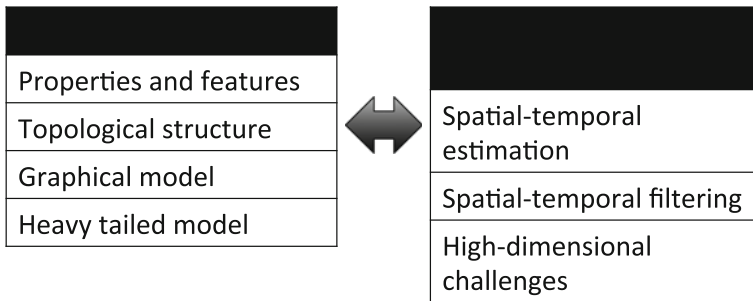
The idea to create this book arose as a response to the discussions and presentations that took place in the first and second annual international workshops on spatial and temporal modeling (STM2013 and STM2014), both of which were held in the Institute of Statistical Mathematics (ISM), Tokyo, Japan. These workshops were cohosted by Prof. Tomoko Matsui (ISM) and Dr. Gareth W. Peters (UCL). It was apparent after these workshops were completed that the wide range of participants from various backgrounds including probability, statistics, applied mathematics, physics, engineering, and signal processing as well as speech and audio processing had been recently developing a range of new theory, models, and methods for dealing with spatial and temporal problems that would be beneficial to document for a wider scientific audience.

Therefore, this book is intended to bring together a range of new innovations in the area of spatial and temporal modeling in the form of self-contained tutorial chapters on recent areas of research innovations. Since it is based on contributions from a range of world experts in spatial and temporal modeling who participated in the workshop, it reflects a cross section of specialist information on a range of important related topics. It is the aim of such a text to provide a means to motivate further research, discussion, and cross-fertilization of research ideas and directions among the different research fields representative of the authors who contributed.

While this book covers more of the theoretical aspects of spatial-temporal modeling, its companion book, also in the Springer Briefs series, titled *Modern Methodology and Applications in Spatial-Temporal Modeling*, complements this book for practitioners as it covers a range of new innovations in methodology for modeling and applications. This book aims to provide a modern introductory tutorial on specialized theoretical aspects of spatial and temporal modeling. The areas covered involve a range of topics which reflect the diversity of this domain of research across a number of quantitative disciplines. For instance, Chap. 1 provides modern coverage of particle association measures that underpin the theoretical properties of recently developed random set methods in space and time otherwise known as the class of probability hypothesis density framework (Ph.D. filters).

Chapter 2 deals with an overview of recent advances in Monte Carlo methods for Bayesian filtering in high-dimensional spaces. In particular it explains how one may extend classical sequential Monte Carlo methods for filtering and static inference problems to high dimensions and big-data applications. Chapter 3 deals with an overview of generalized families of processes that extend the class of Gaussian process models to heavy-tailed families known as alpha-stable processes. In particular it covers aspects of characterization via the spectral measure of heavy-tailed distributions, and it then provides an overview of their applications in wireless communications channel modeling. Chapter 4 concludes with an overview of analysis for probabilistic spatial percolation methods as would be relevant in the modeling of graphical networks and connectivity applications in sensor networks which also incorporate stochastic geometry features.

### Spatial-temporal processes



We first note that each chapter of this book is intended to be a self-contained research-level tutorial on modern approaches to the theoretical study of some aspect of spatial and temporal statistical modeling. However, to guide the reader in considering the sections of this book we note the following relationships between chapters. Chapters 1 and 2 cover recent advances in spatial tracking and state space modeling settings in high-dimensional contexts. The first arises in multiple target tracking settings and is based on extensions of sequential Monte Carlo methods for such contexts which have become known as probability hypothesis density filters. Chapter 2 deals with the class of high-dimensional state space models and introduces different approaches one can adopt to tackle the curse of dimensionality that the standard SMC method suffers from when the state space is high dimensional. In particular it introduces ideas of blocked particle filters, discusses recent space–time particle filters and studies, and compares these to the recently developed class of methods known as sequential Markov chain Monte Carlo (SMCMC) methods.

Chapters 3 and 4 are not so much focused on the estimation of latent process models in spatial–temporal settings, but instead focus on the study of phenomena that have been developed recently to characterize extremes in spatial–temporal settings. In this regard the fourth chapter discusses new approaches to the characterization of heavy-tailed stochastic processes, focusing specifically on the

$\alpha$ -stable family. The final chapter constructs characterizations of spatial processes from a geometrical perspective, focusing on spatial network structures, random graphs and the study of certain connectivity phenomena for such graphical structures. The chapter introduces ideas that can be used to characterize and understand random graphical models that are growing in popularity in tracking multiple objects and populations, finance, ecology, and social network analysis.

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