

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) and the first workshop on complex systems modeling and estimation challenges in big data (CSM2014), all 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 variety of new theory, models, and methods for dealing with spatial and temporal problems that would be beneficial to document for a wider scientific audience.

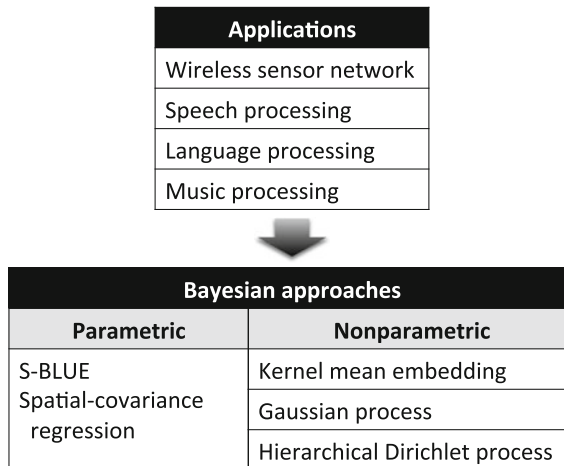
Therefore, this book is intended to bring together a range of new innovations in the area of spatial and temporal modeling in the form of self-contained tutorial chapters on recent areas of research innovations. Since it is based around contributions from a selection of world experts in spatial and temporal modeling who participated in the workshop, it reflects a cross section of specialist information on a range of important topics in spatial and temporal modeling and application. 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.

Whilst this book covers more of the practical and methodological aspects of spatial-temporal modeling, its companion book, also in the Springer Briefs series, titled *Theoretical Aspects of Spatial-Temporal Modeling*, complements this book for theoreticians as it covers a range of new innovations in theoretical aspects of modeling. The chapters in this book cover the topics summarized in the figure.

This book aims to provide a modern introductory tutorial on specialized methodological and applied 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, the first chapter

covers nonparametric Bayesian inference via a recently developed framework known as kernel mean embedding that has had a significant influence in machine learning disciplines. The second chapter covers nonparametric statistical methods for spatial field reconstruction and exceedance probability estimation based on Gaussian process-based models in the context of wireless sensor network data. The third chapter covers signal processing methods applied to acoustic mood analysis based on music signal analysis. The final chapter covers models that are applicable to time series modeling in the domain of speech and language processing. This includes aspects of factor analysis, independent component analysis in an unsupervised learning setting. Then it moves to cover more advanced topics on generalized latent variable topic models based on hierarchical Dirichlet processes which have been developed recently in nonparametric Bayesian literature.

Applications and the Bayesian approaches



We first note that each chapter of this book is intended to be a self-contained research-level tutorial on modern approaches to the practical and methodological 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. The first and second chapters cover recent advances in machine learning-based methodologies for nonparametric estimation procedures. The first chapter addresses the recent topic of kernel mean embedding methods, which are now becoming popular approaches to performing high-dimensional state-space modeling problems as well as addressing problems with intractable likelihood in filtering applications. These recent nonparametric inference methods with positive definite kernels have been developed to utilize the kernel mean expression of distributions. In this approach, the distribution of a variable is represented by the kernel mean, which is the mean element of the random feature vector defined by the kernel function, and the relation among variables is expressed

by covariance operators. This general methodology is starting to have important applications in many spatial and temporal modeling settings.

The second and third chapters also consider nonparametric models, focussing on the class of Gaussian process models, the second chapter looking at spatial models, and the third chapter looking at state-space models. In the second chapter new methods to model spatial data via combinations of Gaussian process models with observations of mixed type, discrete, and continuous. It develops a framework for spatial field reconstruction and establishes efficient spatial best linear unbiased estimators for this spatial field estimation given observations. In addition, an estimation framework based on a covariance regression model is established to perform parameter estimation and introduce covariates into the spatial covariance function structure. In the third chapter state-space models with Gaussian process state or observation equations are considered in the application of speech and music emotion recognition.

The final chapter also studies speech and language processing, this time focusing on topic models for structural learning and temporal modeling from unlabeled sequential patterns. The nonparametric models developed in this chapter are based on the family of hierarchical Dirichlet processes and are considered in a Bayesian formulation. The chapter also discusses, in addition to construction of such models, the variational Bayes- and MCMC-based estimation procedures for such models.

Tokyo, Japan
August 2015

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Modern Methodology and Applications in
Spatial-Temporal Modeling

Peters, G.W.; Matsui, T. (Eds.)

2015, XV, 111 p. 17 illus., 4 illus. in color., Softcover

ISBN: 978-4-431-55338-0