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## Preface

Interest in time series analysis and image processing has been growing very rapidly in recent years. Input from different scientific disciplines and new theoretical advances are matched by an increasing demand from an expanding diversity of applications. Consequently, signal and image processing has been established as an independent research direction in such different areas as electrical engineering, theoretical physics, mathematics or computer science. This has lead to some rather unstructured developments of theories, methods and algorithms. The authors of this book aim at merging some of these diverging directions and to develop a consistent framework, which combines these heterogeneous developments. The common core of the different chapters is the endeavour to develop and analyze mathematically justified methods and algorithms. This book should serve as an overview of the state of the art research in this field with a focus on nonlinear and nonparametric models for time series as well as of local, adaptive methods in image processing.

The presented results are in its majority the outcome of the DFG-priority program SPP 1114 “Mathematical methods for time series analysis and digital image processing”. The starting point for this priority program was the consideration, that the next generation of algorithmic developments requires a close cooperation of researchers from different scientific backgrounds. Accordingly, this program, which was running for 6 years from 2001 to 2007, encompassed approximately 20 research teams from statistics, theoretical physics and mathematics. The intensive cooperation between teams from different specialized disciplines is mirrored by the different chapters of this book, which were jointly written by several research teams. The theoretical findings are always tested with applications of different complexity.

We do hope and expect that this book serves as a background reference to the present state of the art and that it sparks exciting and creative new research in this rapidly developing field.

This book, which concentrates on methodologies related to identification of dynamical systems, non- and semi-parametric models for time series,

stochastic methods, wavelet or multiscale analysis, diffusion filters and mathematical morphology, is organized as follows.

The Chap. 1 describes recent developments on multivariate time series analysis. The results are obtained from combining statistical methods with the theory of nonlinear dynamics in order to better understand time series measured from underlying complex network structures. The authors of this chapter emphasize the importance of analyzing the interrelations and causal influences between different processes and their application to real-world data such as EEG or MEG from neurological experiments. The concept of determining directed influences by investigating renormalized partial directed coherence is introduced and analyzed leading to estimators of the strength of the effect of a source process on a target process.

The development of surrogate methods has been one of the major driving forces in statistical data analysis in recent years. The Chap. 2 discusses the mathematical foundations of surrogate data testing and examines the statistical performance in extensive simulation studies. It is shown that the performance of the test heavily depends on the chosen combination of the test statistics, the resampling methods and the null hypothesis.

The Chap. 3 concentrates on multiscale approaches to image processing. It starts with construction principles for multivariate multiwavelets and includes some wavelet applications to inverse problems in image processing with sparsity constraints. The chapter includes the application of these methods to real life data from industrial partners.

The investigation of inverse problems is also at the center of Chap. 4. Inverse problems in image processing naturally appear as parameter identification problems for certain partial differential equations. The applications treated in this chapter include the determination of heterogeneous media in subsurface structures, surface matching and morphological image matching as well as a medically motivated image blending task. This chapter includes a survey of the analytic background theory as well as illustrations of these specific applications.

Recent results on nonlinear methods for analyzing bivariate coupled systems are summarized in Chap. 5. Instead of using classical linear methods based on correlation functions or spectral decompositions, the present chapter takes a look at nonlinear approaches based on investigating recurrence features. The recurrence properties of the underlying dynamical system are investigated on different time scales, which leads to a mathematically justified theory for analyzing nonlinear recurrence plots. The investigation includes an analysis of synchronization effects, which have been developed into one of the most powerful methodologies for analyzing dynamical systems.

Chapter 6 takes a new look at structured smoothing procedures for denoising signals and images. Different techniques from stochastic kernel smoother to anisotropic variational approaches and wavelet based techniques are analyzed and compared. The common feature of these methods is their local and

adaptive nature. A strong emphasize is given to the comparison with standard methods.

Chapter 7 presents a novel framework for the detection and accurate quantification of motion, orientation, and symmetry in images and image sequences. It focuses on those aspects of motion and orientation that cannot be handled successfully and reliably by existing methods, for example, motion superposition (due to transparency, reflection or occlusion), illumination changes, temporal and/or spatial motion discontinuities, and dispersive nonrigid motion. The performance of the presented algorithms is characterized and their applicability is demonstrated by several key application areas including environmental physics, botany, physiology, medical imaging, and technical applications.

The authors of this book as well as all participants of the SPP 1114 “Mathematical methods for time series analysis and digital image processing” would like to express their sincere thanks to the German Science Foundation for the generous support over the last 6 years. This support has generated and sparked exciting research and ongoing scientific discussions, it has lead to a large diversity of scientific publications and – most importantly- has allowed us to educate a generation of highly talented and ambitious young scientists, which are now spread all over the world. Furthermore, it is our great pleasure to acknowledge the impact of the referees, which accompanied and shaped the developments of this priority program during its different phases. Finally, we want to express our gratitude to Mrs. Sabine Pfarr, who prepared this manuscript in an seemingly endless procedure of proof reading, adjusting images, tables, indices and bibliographies while still keeping a friendly level of communication with all authors concerning those nasty details scientist easily forget.

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