BOOK REVIEW

Nonlinear Dynamics and Statistics

edited by Alistair I. Mees
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The Volume comprises some of the papers presented at the Workshop on Nonlinear Dynamics and Statistics, held in September 1998, at the Isaac Newton Institute, Cambridge University, as part of the "Nonlinear and Non-stationary Signal Processing" programme.

The aim of the Workshop was to bring together professionals in theoretical and applied nonlinear dynamics, statistics, signal processing, and systems engineering, and let them realise and discuss how prolific and impacting their work had been so far, so that to meet the diversity of applications and the objectives of practitioners. The non-linear dynamics community attending the Workshop was unanimous on expressing that the appropriation of the already taken insights and of the experience in dynamic reconstruction turned imperative for outsiders. The Workshop many thought-nourishing and action-inspiring communications did testify the success of the event. In the editor's acceptance this Volume, far from being only a selection from among significant and repercussion contributions, makes a red thread through statisticians' and engineers' thinking patterns for the moment and for the perspective.

The authors' view of dynamic reconstruction is no longer that of a privilege of physics and applied mathematics; they direct attention to computational algorithms acting as models in the reconstruction theory. Once concerned with the modelling concept, the authors of the papers in the Volume stepped the doorway of reconstruction theory, conscious of the fact that all things in the world are put in an interdependence, an interdependence however allowing models are composed, based on parts of them (decomposed parts). Knowledgeable readers would realise that the reconstruction theory avoids formal descriptions and uses high performant computational algorithms, uses data instead of equations, and is concerned with the geometry of phase space. The reconstruction theory proposes relevant descriptions and enables computer based predictions and estimates.

As the Workshop was ideatically controversial, the editor tried and succeeded to reflect the kernel of debates through including those of the papers that discuss significant topics for the applied dynamics field. The Volume also addresses problems in nonlinear dynamic and time series analysis.

The book has **three Parts**: *Issues in Reconstructing Dynamics*, *Fundamentals*, and *Methods and Applications*. There has been no bias in the fact that the papers entered one Part or the other. They are all meant to invite readers into knowing more about nonlinear dynamics in some Chapters, and into finding that more in the other Chapters.

The **first Part** of the book presents some of the problems faced with when reconstruction of nonlinear dynamics from observed data is attempted.

The paper "***Challenges in Modeling Nonlinear Systems: A Worked Example***" by Henry D.I. Abarbanel describes the situation as seen by the community: it shows what we want to know and what we do know, and it analyzes a data set in a way that will be familiar to most dynamicists, but less customarily, it discusses what is good and bad about this way of doing things.

The second paper "***Disentangling Uncertainty and Error: On the Predictability of Nonlinear Systems***", by Leonard A. Smith discusses a number of fundamental issues in the interaction between observational uncertainty and model error in reconstructed dynamics. Given that all models are misleading, the perfection model is not within our reach, and it is rather difficult to decide which model offers the real understanding. A solution could be that of not to renounce many of the models. The idea of keeping many models occurs later, when Kennel and Mees use weighted models based on work in data compression.

The paper authored by Judd, Small and Mees, and entitled *"**Achieving Good Nonlinear Models: Keep It Simple, Vary the Embedding, and Get the Dynamics Right**"*, points out that modeling dynamics usefully is more than just a question of getting good short-term predictions- an insight that is also a theme of Schoner and Gershenfeld's contribution later in the book-indeed, it is being increasingly recognized as a key question. They also emphasize the importance of separating noise from signal and the consequent usefulness of information theoretic ideas.

Jaroslav Stark, in his paper "***Delay Reconstruction: Dynamics versus Statistics***", makes it clear that the standard embedding process is fraught with danger and should be subject to careful scrutiny. In the process, he mentions many successful extensions: the take-home lesson is perhaps that embedding is even more powerful than is often supposed, but that it needs far more care than is usually exercised.

The paper entitled "***Some Remarks on the Statistical Modeling of Chaotic Systems***", by Dominique Guegan discusses the statistical modeling of chaotic time series and its perils and rewards. That is, of course, the theme of the book: reconstruction requires both dynamics and statistics to be considered, and the author speaks from the informed statistician's viewpoint.

Peter Young, in his contribution entitled " ***The Identification and Estimation of Nonlinear Stochastic Systems***", speaks from the point of view of a system engineer and points out that most practical dynamical problems are best posed as input-output systems, yet they are modeled as autonomous systems in the dynamics community. A merge of his methods with the advance in nonlinear dynamics is long overdue.

Chapters of the **second Part** discuss questions related to modeling nonlinear time series (or reconstructing dynamics). Chapter by chapter dwells, to a larger or smaller extent, on a statistical approach, the principles of the ergodic theory, basic questions in dynamical reconstruction, and on modeling methods. There is a round trip from statistics to dynamics, stochastically taken.

The *first Chapter* of this Part, authored by Andrieu et al, and entitled "***An Introduction to Monte Carlo Methods for Bayesian Data Analysis***", presents a survey of the modern theory of Monte Carlo methods; the great advances made in the past few years mean that many dynamical modeling problems, which are often representable in Bayesian terms, are now partially solvable: something that should improve nonlinear dynamical models immensely.

The paper of Schreiber and Schmitz, " ***Constrained Randomization of Time Series for Nonlinearity Tests***", deals with nonlinearity tests, which have been significant in recent years as a precaution against claiming nonlinearity in the absence of strong evidence.

Steven P. Lalley shows in "***Removing the Noise from Chaos Plus Noise***" that a chaotic system with unbounded noise cannot be de-noised (at least in the conventional sense), and then shows how bounded noise can be tackled successfully.

The paper of Colleen D. Cutler "***Embedding Theorems, Scaling Structures, and Determinism in Time Series***" discusses definitions of deterministic and stochastic for time series and relates these to dynamical systems. She shows that it is not difficult to produce simple examples where the system cannot be reconstructed owing to poor choice of observable data. The Grassberger-Procaccia algorithm converges in these cases even though embedding is never achieved.

"***Consistent Estimation of a Dynamical Map***", by Andrew Nobel, investigates how to approximate dynamics and contrasts deterministic models with models that include dynamic noise, while taking into account the oft-neglected issue of statistical consistency. The investigation sheds light on the question of distinguished deterministic systems from stochastic systems, a question also considered in Guegan's Chapter.

The estimation problem of a system invariant density via Markov models makes the subject of investigation in the paper "***Extracting Dynamical Behaviour via Markov Models***", by Gary Froyland.

This way is often a superior way to compute statistical properties. Knowing the invariant density is arguably both the best than can be done and the best thing to do. This Chapter is a detailed review of the latest results in the area.

Timothy D. Sauer in his paper entitled "***Formulas for the Eckmann-Ruelle Matrix***" shows that a calculation that is implicit in a great deal dynamical analysis – estimation of a local derivative – is more subtle than was thought and has surprising properties in the presence of noise.

The **final Part** of the book is devoted to modeling methods and nontrivial applications.

Dixon et al, present in their paper "***Noise and Nonlinearity in an Ecological System***" a successful fisheries model and describe the modeling approach that they used, the S-map method. They add more weight to one of the familiar themes of this book, the need to understand the interplay between noise and nonlinearity.

Bernd Schoner and Neil Gershenfeld discuss, in their paper "***Cluster-Weighted Modeling: Probabilistic Time Series Prediction, Characterization, and Synthesis***", another successful reconstruction method, cluster-weighted modeling, and apply it to an exceptionally challenging problem in synthesis of audio signals: the "digital Stradivarius".

Matthew B. Kennel and Alistair I. Mees in the paper "***Data Compression, Dynamics, and Stationarity***" borrow work from the data compression literature and demonstrate that it has a lot to offer the dynamics community; they show an application to stationary testing of fluidized-bed reactors. The models that are produced are inherently probabilistic, and predictions are conditioned on a discrete analogue of variable embeddings.

The paper "***Analyzing Nonlinear Dynamical Systems with Nonparametric Regression***", by Henning U. Voss uses nonlinear non-parametric regression for the analysis of experimental data, which can greatly simplify the modeling process if there is a certain amount of knowledge available about the system's structure.

Albano et al, in their paper "***Optimization of Embedding Parameters for Prediction of Seizure Onset with Mutual Information***" show how estimation of average mutual information, applied in an unusual way, can be useful in analysis of EEG signals, with specific application to early warning of epileptic seizures.

Milan Palůs shows, in his paper entitled "***Detection of a Nonlinear Oscillator Underlying Experimental Time Series: The Sunspot Cycle***", a deep understanding of both dynamical and statistical fundamentals to examine the well-known sunspot data series and concludes that it is indeed most likely generator by a nonlinear dynamical system in spite of the fact that previously the best linear stochastic models seemed to be as good as the best nonlinear ones.

The material presented in the book is very well organized, presented with clarity, and the reader's understanding is helped with many examples. It is worth mentioning the fluency of the style, the absence of typographical errors and the accuracy of graphical material , which all make the book agreeable to read.

Finally, the reviewer considers that this is a good book in terms of the topics selected and the approach adopted, and fully recommends it to researchers and practitioners in the field of nonlinear dynamics and statistics, who will find the text a helpful guide to proper construction of qualitative description models, to be used for quantitative predictions and estimates.

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