

Springer Proceedings in Complexity

Stavros G. Stavrinides
Mehmet Ozer *Editors*

Chaos and Complex Systems

Proceedings of the 5th International
Interdisciplinary Chaos Symposium

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Editors

Chaos and Complex Systems

Proceedings of the 5th International
Interdisciplinary Chaos Symposium

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Preface

Nonlinear and complex systems, although deterministic, demonstrate a strange behavior, due to widely diverging outcomes, provoked by small variations in initial conditions or system parameters that lead to inobservance of long-term system-behavior prediction. This very abstractive description explains the reason why Chaos Theory, Nonlinear Dynamics, and Complexity are fascinating areas of interdisciplinary scientific research with a wide range of applications. The interdisciplinary nature and ubiquity of complexity and chaos provide scientists with a motivation to pursue general theoretical tools and frameworks. Nonlinearity and complexity give rise to emergent behaviors, producing novel and interesting phenomena ranging from science and engineering to social sciences, finance, and economy. Consequently, Nonlinear Dynamics, Chaos Theory, and the Science of Complexity appear to have a tremendously increasing Interest, nowadays.

The aim of all the *International, Interdisciplinary Symposia on Chaos and Complex Systems (CCS)* is to bring together scientists, engineers, economists, and social scientists, creating a vivid forum, where discussions on the latest insights and results obtained in the area of Complexity, Nonlinear Dynamics, and Chaos Theory, as well as their interdisciplinary applications, take place.

The scope of the *5th International Interdisciplinary Symposium on Chaos and Complex Systems*, better known as *CCS 2019*, which took place in Antalya, Turkey, on May 09–12, 2019, has been enriched with variety of contemporary, interdisciplinary topics, encompassing including but not limited to fundamental theory of nonlinear dynamics, networks, circuits, systems, biology, evolution and ecology, fractals and pattern formation, as well as nonlinear time-series analysis, neural networks, sociophysics and econophysics, management complexity and global systems.

Already from the *4th International Interdisciplinary Symposium on Chaos and Complex Systems* that took place during May 2012, the organizers are publishing the corresponding proceedings with the *Springer Complexity series*. Faithful to this tradition, the book that you hold in your hands includes some of the papers presented in the present symposium, addressing some of the areas mentioned above. These proceedings, together with the previous ones, aspire to serve as a compact

reference book on nonlinear systems, catering to research scholars, interested readers, and advanced learners from multidisciplinary areas.

We would like to express our thanks to the Symposium's International Scientific Committee and the Chairs of the Technical Program Committee and the Special Session Committee, as well as to all those who have contributed to this conference, for their support and advice. We are also grateful to Prof. Dr. Ronald Tetzlaff for his support and the wonderful opening lecture. Our thanks are also due to Prof. Tiziana Di Matteo for the plenary talk, her support, and incentive encouraging. Finally, the editors of this tome are grateful to Springer for the quality of this edition.

We hope that this conference series, which begun in 2006, will become a strange attractor for researchers.

Thessaloniki, Greece
Istanbul, Turkey

Stavros G. Stavrinides
Mehmet Ozer

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Part I
Nonlinear Dynamics and Timeseries
Analysis

Chapter 1

Determinism Testing of Low-Dimensional Signals Embedded in High-Dimensional Multivariate Time Series



C. Frühauf, S. Hartmann, B. Seifert and C. Uhl

Abstract High-dimensional multivariate time series often consist of a low-dimensional deterministic part. To extract this contribution it is crucial to reduce the dimension of the signal using a dimensionality reduction method. There are three possible approaches, which are compared in this paper: Takens' delay embedding theorem, a combinatorial approach and projection approaches. After dimensionality reduction of the time-series, the Kaplan-Glass determinism test is applied to compare the obtained signals with respect to deterministic behavior. All introduced methods are applied to simulated noisy data and to EEG data during and out of epileptic seizures.

1.1 Introduction

The test for determinism introduced by Kaplan and Glass [1] is used to distinguish between deterministic and stochastic dynamics. It can be applied to embedded time series with time delay and to multivariate time series, e.g. epileptic EEG data, to characterize the deterministic dynamics, which is affected by chaos. The measure of the determinism called k is obtained by computing the total average length of all average unit vectors. The unit vectors are generated by each pass of the trajectory through a box. The boxes are created before by coarse graining the phase space. The determinism test is based on the observation that the tangent to trajectory generated by a deterministic system is a function of position in phase space. Therefore, all tangents to the trajectory in a small area of phase space will have similar orientations [1]. Furthermore, if the trajectory is deterministic the value k will be close to 1 and the system could be described by a set of differential equations. In time series with stochastic components, the value will be smaller than 1, cf. [1].

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