

Preface

The main novelty of this book is the consideration of chaos as an *input* for differential and hybrid equations. More precisely, we insert chaos on the right-hand side of the equations and investigate the results of perturbation. Moreover, we investigate many possible consequences of the input–output analysis in systems with many compartments. This is what makes our book on chaos unique among all others.

Let us give some arguments toward the importance of the input–output analysis of chaos for both theory and applications:

1. In the theory of dynamical systems, a large number of results use the input–output analysis. For example, there are many theorems that can be loosely formulated as follows: if a perturbation is periodic (bounded, almost periodic), then there is a unique periodic (bounded, almost periodic) solution. Generally speaking, our results can be formulated in the following way: if a perturbation is chaotic, then there exists a chaos in the set of solutions. Thus, one can say that our main proposal is to return investigation of chaos into the mainstream of classical differential/difference equations theory and, consequently, a huge number of rigorous mathematical methods, numerical instruments, and applications that rely on the input–output analysis will be involved for the investigation of chaotic processes.
2. Despite the fact that many distinguished specialists in the chaos theory and mathematics have been involved in the investigation, there are still many challenging problems related to the origin of the chaos theory. For instance, we do not have a rigorously approved chaos in Lorenz systems, Duffing equations, and other systems. Moreover, there is no universal method to detect chaos in multidimensional systems. Hopefully, the input–output analysis will give new opportunities for the analyses of the basic models and help to unify the knowledge of chaos. We believe that the exploitation of the mechanism in the considered models can give mathematical clarity there.

3. The input–output analysis can become a strong instrument in applications to real-world problems through the modeling of chaos expansion. We hope that unpredictability of weather, economical unpredictability, and irregularity as a global phenomenon will be reflected in mathematical investigations more comprehensively through this machinery. This is true not only for atmospheric or economic processes, but also for any large systems in biology, neural networks, and computer sciences. Utilization of the input–output analysis in cryptography and deciphering may also give effective results. The input–output analysis is very popular, for instance, in mechanics, chemistry, biology, cryptography, etc. Consequently, one can suppose that what we have suggested has to be realized for real-world problems of various natures.
4. We describe the expansion of chaos on the basis of the input–output mechanism using the concept of *morphogenesis* to emphasize that the expansion keeps the geometrical properties of chaos. Furthermore, it is not surprising that the replication of chaos, introduced in the book, relates to concepts of science with broad applications: *self-organization*, *synergetics*, *chaos-order relations*, *thermodynamics*, *biological patterns*.

The book is attractive in the mathematical sense, since we have introduced rigorous description of chaos for systems with continuous time for the first time. This may give a push for the functional analysis of chaos to involve the operator theory results, etc. Hopefully, our approach will give a basis for deeper comprehension and the possibility to unite different appearances of chaos. In this framework, we also hope that the results can be developed for partial differential equations, integro-differential equations, functional differential equations, evolution systems, etc.

A part of the book is devoted to problems of economics. We have analyzed chaos extension in economic models. Unpredictability in economics as sensitivity in dynamical models is considered, and on that basis, global extension of unpredictability is discussed.

The presence of chaos in neural networks is indispensable, and as applications of our results, replication of chaos by neural networks is presented in a separate chapter in this book.

We pay great attention to expansion of chaos through Lorenz models in meteorology. A special mathematical analysis has been made, since only dissipativeness property of a system is used to prove the chaos presence in perturbed systems.

Entrainment of limit cycles by chaos is discovered numerically through specially designed unidirectional coupling of two glow discharge-semiconductor systems. The result demonstrates that the input–output machinery is working effectively for partial differential equations. Chaotic control is through the external circuit equation and governs the electrical potential on the boundary. The expandability of the theory to collectives of glow discharge systems is discussed, and this increases the potential of applications of the results.

The content of the book is a good background for applications in mechanics, biology, molecular biology, physiology, pharmacology, secure communications, neural networks, and other real-world problems involving complex behavior of models. Since chaos is present everywhere, we can say that our results are applicable in any field, where differential and difference equations are utilized as models.

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