Preface

This is the fourth volume of the collection of essays entitled *Applications of Chaos and Nonlinear Dynamics in Science and Engineering*, which has been addressed to Master and Ph.D. Students, as well as to specialists of disciplines other than the hard sciences, in order to help them familiarize with the theory and the applications of nonlinearity, and its use in describing complex phenomena.

As illustrated in the previous volumes, terms such as nonlinear dynamics, chaos and complexity have pervaded the vocabulary of almost all fields of science and technology. As a matter of fact, current mathematical descriptions of evolving phenomena consist of nonlinear ordinary or partial differential equations, of various kinds of stochastic processes and of nonlinear space and time discrete iterative schemes. In the deterministic cases, a typical situation is that in which the propagation of uncertainties is exponential in time, a phenomenon known as sensitive dependence on initial conditions, and concisely and suggestively called deterministic chaos.

To understand the reasons why certain terms have become common in many different fields, it suffices to observe that nonlinearities appear in feedback phenomena, which are ubiquitous in nature, and generically in the evolution equations of systems consisting of interacting parts or interacting with an external environment. Furthermore, any measurement one may perform, like any estimate of the initial state of any material object, is bound to be affected by uncertainties, which propagate in time leading to the conclusion that a degree of unpredictability is intrinsic, in practice as well as in principle, to all time dependent phenomena. For this reason, the study of nonlinear evolutions is commonly associated with statistical concepts, and relies on measures such as the Lyapunov exponents and various kinds of dynamical entropies.

In the previous volumes, we have presented a vast collection of examples, treated explicitly and in moderately technical terms. Indeed, these concepts have in the past decades turned useful in countless practical applications—beyond the mathematical and physical literature in which they have been mostly developed—ranging from engineering to biology, medicine, computer and telecommunication sciences, etc. We have thus followed an approach which we deem suitable to a vast readership, proposing essays written in the form of tutorials. In this last volume, we complete our survey and introduction to nonlinear, chaotic and complex phenomena, considering some issues of higher theoretical content than in the previous volumes, but preserving the mildly technical style of the previous volumes.

Part I concerns nonlinearities in transport of energy and matter, with one contribution by L. Stricker and L. Rondoni on models of heat transport and their mechanical properties, one contribution on the general theory of diffusion, by G. Boffetta, G. Lacorata and A. Vulpiani, and one contribution by M. Colangeli on the relation between the Boltzmann equation and hydrodynamics.

In Part II, we have three contributions on chaos and synchronization in complex networks: one by J. Stroud, M. Barahona and T. Pereira on modular networks, one by P. Carl on the evolution of climate, and one by A. Tai and S. Jalan on the use of random matrices. The chapters are well illustrated with recent developments on the subject area and possible practical applications.

Part III has two contributions on phase space reconstruction and on biological patterns, respectively, by S. K. Palit, S. Mukherjee, S. Banerjee, M.R.K. Ariffin and D. K. Bhattacharya, and by M. Banerjee. The theories are well illustrated and supported with analytical and numerical results.

Part IV concerns the use of chaos in field programmable gate arrays. This chapter is very useful as an introduction to the subject area.

We hope that this collection of examples, combined with those reported in the previous three volumes have covered a sufficiently wide spectrum of subjects, in terms suitable to a wide audience, interested in importing dynamical concepts in their disciplines, without recourse to sophisticated mathematical tools. The concepts of nonlinear dynamics are indeed proving more and more useful in all fields of research.

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