Nayfeh, Ali H.; **Balachandran, Balakumar**
Applied nonlinear dynamics: analytical, computational, and experimental methods. (English) Zbl 0848.34001
Wiley Series in Nonlinear Science. Chichester: John Wiley & Sons. xv, 685 p. (1995).

In the preface, after giving a list of 42 books on nonlinear dynamics that appeared between 1980 and 1994, the authors formulate their arguments for presenting another book on the subject as follows: "We are of the opinion that the books on nonlinear dynamics published thus far have a strong bias toward analytical methods, or experimental methods, or numerical methods. As these methods are complementary to each other, a person being taught nonlinear dynamics should be provided with a flavor of all the different methods. This is one of the intentions in writing this book. Another intention was to include some of the recent developments in the control of nonlinear dynamics of systems." The book consists of eight chapters. In Chapter 1, the authors introduce (discrete-time and continuous-time) dynamical systems as well as the concepts of attracting sets, stability and attractors. In Chapters 2 to 5 they address the different types of attractors: equilibria, periodic solutions, quasiperiodic solutions and chaotic attractors, each in parallel for maps and continuous-time systems. As the authors state, "these chapters are not written within a mathematically rigorous framework. We present some relevant theorems and their implications. Proofs are not provided in this book, but references that provide them are included." The presentation is mainly based on (more than 100) specific examples which are used to illustrate the notions and methods under discussion. An impressive diversity of results is presented in these chapters, in particular in Chapter 5 which, among others, contains sections on the different routes to chaos (period-doubling scenario, intermittency mechanisms, quasiperiodic routes), on crises, Melnikov theory, and bifurcation of homoclinic orbits. A survey on useful methods of investigation is given in Chapters 6 and 7. Chapter 6 deals with continuation methods for equilibria and period solutions; Chapter 7 presents tools to analyze motions: time histories, state space portraits, Fourier transforms, Poincaré sections, autocorrelation functions, Lyapunov exponents, dimension calculations. Chapter 8 surveys some recent results on feedback-based control of bifurcations following the work of E. H. Abed and his coworkers, on control of chaos along the lines of Ott/Grebogi/Yorke, and on synchronization of chaotic motions. The book is complemented by a large number of exercises of different complexity and by an extensive bibliography (74 pp.) with particular emphasis on applications. In particular it can be recommended as a textbook for students in engineering and applied sciences. Mathematicians, delicate as they are, may feel unhappy with some fuzzy formulations (so, e.g., "an orbit of (1) $x_{k+1} = 2x_k(1 - x_k)$ initiated at $v_0 = 0.4$ is $\{0.4,\ 0.48,\ 0.4992,\ 0.49999872,\ 0.5, \dots, 0.5\}$" (p. 21) (Of course, the fifth term is not equal to 0.5 even if some "experimental method" says it is. And what is the meaning of the last 0.5 in this infinite sequence?), or "Example 1.12. The solution $x_k = 0.5$ of (1) is asymptotically stable. This is so because $x_k = 0.5$ is Lyapunov stable and the separation between the orbits initiated at $u_0 = 0.5$ and $v_0 = 0.4$ or any other starting point in a small neighborhood of u_0 is very small for $k \geq 4$" (p. 23), or "by finding the largest possible region for which the conditions of Krasovskij's theorem are satisfied, one can determine the domain of attraction of x_0" (p. 29). (This is obviously not true if only one particular Lyapunov function is taken into account. And, as is well known, the region $\frac{1}{2}x_2^2 + \frac{1}{2}x_1^2 + \frac{1}{4}x_1^4 < \frac{1}{4}$ is not the domain of attraction of the origin of $\dot{x}_1 = x_2$, $\dot{x}_2 = -x_1 + x_1^3 - 2\mu x_2$, $\mu > 0$, but only a part of it).

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MSC:

- 34-01 Introductory exposition (textbooks, tutorial papers, etc.) pertaining to ordinary differential equations
- 34C23 Bifurcation theory for ordinary differential equations
- 34C25 Periodic solutions to ordinary differential equations
- 34C27 Almost and pseudo-almost periodic solutions to ordinary differential equations
- 34C28 Complex behavior and chaotic systems of ordinary differential equations
- 37-XX Dynamical systems and ergodic theory
- 34C37 Homoclinic and heteroclinic solutions to ordinary differential equations
- 34D45 Attractors of solutions to ordinary differential equations
- 58-01 Introductory exposition (textbooks, tutorial papers, etc.) pertaining to global analysis

Keywords:

nonlinear dynamics; dynamical systems; attractors; routes to chaos; control of bifurcations; control of chaos; textbook