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Book Review: *An Exploration of Chaos*

An Exploration of Chaos. John Argyris, Gunter Faust, and Maria Haase, North-Holland, Amsterdam, 1994.

This is an introductory book written in a style quite distinct from many other similar books on chaos. It is meant as a book "aimed not at mathematicians and theoretical physicists, but rather at budding scientists and engineers of all fields" and the authors take their audience seriously, sometimes to a fault. The topics dealt with are fairly 'mainstream' and the coverage of these topics is not excessive. But each topic is discussed with phenomenally detailed explanation, with almost maternal solicitude. The result is a book which runs to over 700 pages, omitting very little material required to understand the topics covered. For example, the chapter on chaos in nondissipative systems begins with Newton's laws and d'Alembert's principle and leads the reader up to canonical transformations and integrability (including the description of Kepler's problem as an illustration) before embarking on material specifically related to chaos.

In Chapters 2 and 3 basic concepts and definitions are introduced, including definitions of dynamical systems, phase space, first integrals, manifolds, qualitative vs. quantitative analysis, stability, fixed points, Poincaré sections, and maps. These chapters also outline the nature of the problems discussed in the book (a descriptive summary of the actual contents makes up Chapter 1).

Chapter 4 discusses dynamical systems without dissipation. Past the introductory material mentioned earlier, this chapter contains a discussion of the stability of perturbed Hamiltonian systems—KAM theory, invariant tori, disintegration of invariant tori, and the generation of chaotic behaviour near homoclinic points. The chapter closes with a detailed discussion of the Hénon map as an example.

Chapter 5 discusses systems with dissipation, starting with the ideas of phase space volume contraction and strange attractors. Analysis of power spectra, autocorrelations, and Lyapunov exponents are described in

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great detail, with all necessary background material. Subsequent sections are devoted to the various dimensions characterizing attractors and the Kolmogorov–Sinai entropy as a measure of chaos.

Chapter 6 deals with local bifurcation theory, discussing qualitative changes that arise in dynamical systems with the change of (for the most part, just one) control parameter(s). The chapter describes the study of the centre manifold and normal forms to analyze local bifurcations, and describes in detail the logistic map as a specific case study, including the renormalization procedure to determine the Feigenbaum constants. The chapter ends with an interesting outline of synergetics.

Chapter 7 describes the Lorenz system, beginning with the derivation of the hydrodynamic equations for convection problems and the simplifications resulting in the Lorenz equations (one of which, due to a typographical error, is "left as an exercise to the reader").

Chapter 8 describes the routes to turbulence. It begins with a description of Landau's analysis, the critical study of Ruelle and Takens of this scenario, and their introduction of the notion of a strange attractor. Subsequently, the universal characteristics of the transition to chaos, the Feigenbaum route to chaos through period doublings, the quasiperiodicity, and intermittency routes are described. A brief section on the control of chaos closes the chapter.

The final chapter (Chapter 9) of the book describes computer experiments on a number of dynamical systems, applied to a variety of scientific problems. These include bone remodelling, the Hénon map, the Lorenz system, Van der Pot equation, Duffing equation, Julia sets, morphology of Arnol'd tongues, oscillatory kinetics of chemical reactions on surfaces, and instances of chaotic behaviour in the solar system. The last two topics are covered in considerable detail.

As appropriate to their intended audience, the authors start out all their discussions at an elementary level, but carry it through to a fairly high level of depth and detail. The reader will not find much background material or explanation missing. The style of presentation is very clear. In addition to the impressive colour plates, the illustrative quality of the figures and diagrams is excellent throughout. The only serious omission, for a textbook, is the absence of exercises. While the topics covered themselves are not too diverse, the authors have extended themselves to accommodate the diversity of the intended audience. As described above, most of the material in the book deals with physical/mechanical systems, with relatively less attention paid to topics such as fractal sets and discrete maps. While computational methods are described in sufficient detail, the survey of experimental results and methods is not as extensive. An instructor intending to use the book as a textbook may have to make a selection of topics appropriate to nature of the course, given the exhaustive nature of explanatory text. One unfortunate disincentive for using this book as a text is the price, which at more than $100 (paperback) is prohibitive. However, the authors have made an effort to and have largely succeeded in writing a very accessible book which nevertheless conveys the principles of chaos nontrivially. As such, it is a welcome addition to the pedagogic literature on chaos.

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