Preface

Besides the idea from the first volume of this book which was focused on various methods to diagnose the complex behavior of nonlinear dynamic system, this volume will additionally take an insight into applying different control strategies to stabilize the complex behavior of the nonlinear dynamic system. The motivation of this volume is derived from the discussions among the researchers and engineers taking part in the ASME 2012 and 2011 Congress in the track of Dynamics Systems and Control, Optimal Approaches in Nonlinear Dynamics, which were organized by the editors. Processes in industries such as robotics and the aerospace industry typically have strong nonlinear dynamics. Nonlinear systems give rise to interesting phenomena such as limit cycle, bifurcation, and chaos. They are all harmful motions since an ideal system will require holding the set point and not oscillating around it. Therefore, these behaviors of dynamical systems need to be controlled to be stabilized. The usual objective of a control theory is to calculate solutions for the proper corrective action from the controller that result in system stability.

In the role of the editors as well as the chapter contributors of this book, we have tried to present a collection of chapters showing the theoretically and practically sound nonlinear approaches and their engineering applications in various areas, in hoping that this book may provide useful tools and comprehensible examples of solving, modeling, and simulating the nonlinear systems existing in the real world. The carefully selected chapters contained in this book reflect recent advances in nonlinear approaches and their engineering applications. The book intends to feature in particular the fundamental concepts and approaches of nonlinear science and their applications in engineering and physics fields. It is anticipated that this book may help to promote the development of nonlinear science and nonlinear dynamics in engineering, as well as to stimulate research and applications of nonlinear science and nonlinear dynamics in physics and engineering practices. It is also expected that the book will further enhance the comprehension of nonlinear science and stimulate interactions among scientists and engineers who are interested in nonlinear science and who find that nonlinearity and complexity of systems play an important role in their respective fields.

In control theory it is sometimes possible to linearize such classes of systems and apply linear techniques, but in many cases it can be necessary to devise from scratch theories permitting control of nonlinear systems. Differential geometry has been widely used as a tool for generalizing well-known linear control concepts to the nonlinear case, as well as showing the subtleties that make it a more challenging problem. Nonlinear control is the area of control engineering specifically involved with systems that are nonlinear, time-variant, or both. Many well-established analysis and design techniques exist for linear time-invariant (LTI) systems; however, one or both of the controller and the system under control in a general control system may not be a linear time-invariant system, and so these methods cannot necessarily be applied directly. Nonlinear control theory studies how to apply existing linear methods to these more general control systems. Additionally, it provides novel control methods that cannot be analyzed using linear time-invariant system theory. A nonlinear controller can have attractive characteristics though it usually requires more rigorous mathematical analysis to justify its conclusions.

In chaos theory, control of chaos is based on the fact that any chaotic attractor contains an infinite number of unstable periodic orbits. Control of chaos is the stabilization of one of these unstable periodic orbits, by means of small system perturbations. The perturbation must be tiny to avoid significant modification of the system's natural dynamics. Several techniques have been devised for chaos control, and most are developments that require a previous determination of the unstable periodic orbits of the chaotic system before the controlling algorithm can be designed.

With the theme of the book, *Nonlinear Approaches and Engineering Applications 2*, the book covers interdisciplinary studies on theories and methods of nonlinear science and their applications in complex systems such as those in nonlinear dynamics, nanotechnology, fluid dynamics, aerospace structure engineering, mechatronics engineering, control engineering, ocean engineering, offshore structure engineering, mechanical engineering, human body dynamics, and material science. Specifically, by modifying the linear conditions into the nonlinear practical model of shock absorbers, Chap. 1 analytically reviews the flat ride conditions of vehicles and provides design charts to satisfy the required conditions. In Chap. 2, the formulation of tracking mechanism used for a light-tracking system is presented to maximize the collected energy. Chapter 3 focuses on both diagnosing and controlling the nonlinear dynamic responses of a fluttering plate excited by a high-velocity air flow. The approaches presented have research and engineering application significances in the fields of aerodynamics, nonlinear dynamics, aircraft design, and design of space vehicles. Chapter 4 presents the development of a closed-form controller for the tracking control of uncertain real-life multibody systems, which are in general highly nonlinear and intrinsically hard to be modeled. In Chap. 5, the robustness of orthogonal eigenstructure control (OEC) to the failure of the actuators was investigated. It was shown that the control gain was capable of controlling the systems during an actuator failure, as OEC generates the control gain by maintaining the closed-loop eigenvectors within the achievable eigenvectors set. In Chap. 6, the highly nonlinear phenomenon of fluid–structure interaction is discussed, including examples on aircraft flutter. Chapter 7 reports on a study that used computer dynamic simulation to analyze the energy absorption and damage in a new impact attenuator in both numerical modeling and experiment verification level. In Chap. 8, nonlinear Vehicle Seat buzz, squeak, and rattle (BSR) noise are characterized using CAE methodology and then can consequently be partly controlled by managing the seat structure resonant frequencies and mode shapes. Chapter 9 introduces a novel approach to calculate a first-order approximation for point distances from general nonlinear structures. It also proposes an accelerated sampling method for robust segmentation of multiple structures. Chapter 10 reviews mathematical models of mechanical and electromechanical parametric amplifiers.

Level of the Book

This book aims at engineers, scientists, researchers, and engineering and physics students of graduate levels, together with the interested individuals in engineering, physics, and mathematics. This chapter-book focuses on application of the nonlinear approaches representing a wide spectrum of disciplines of engineering and science. Throughout the book, great emphases are placed on engineering applications, physical meaning of the nonlinear systems, and methodologies of the approaches in analyzing and solving for the systems. Topics that have been selected are of high interest in engineering and physics. An attempt has been made to expose the engineers and researchers to a broad range of practical topics and approaches.

The topics contained in this book are of specific interest to engineers who are seeking expertise in nonlinear analysis, mathematical modeling of complex systems, optimization of nonlinear systems, nonclassical engineering problems, and future of engineering.

The primary audience of this book is the researchers, graduate students and engineers in mechanical engineering, engineering mechanics, civil engineering, aerospace engineering, ocean engineering, mathematics, and science disciplines. In particular, the book can be used as a research book for the graduate students to enhance their knowledge by taking a graduate course in the areas of nonlinear science, dynamics, vibration, structure dynamics, and engineering applications of nonlinear science. It can also be utilized as a guide to the readers' fulfillment in practices. The covered topics are also of interest to engineers who are seeking to expand their expertise in these areas.

Organization of the Book

The main structure of the book consists of two parts of analytical and practical nonlinearity, including ten chapters. Each of the chapters covers an independent topic along the line of nonlinear approach and engineering applications of nonlinear science and control theory. The main concepts in nonlinear science and engineering applications are explained fully with necessary derivatives in detail. The book and each of the chapters are intended to be organized as essentially self-contained. All necessary concepts, proofs, mathematical background, solutions, methodologies, and references are supplied except for some fundamental knowledge well known in the general fields of engineering and physics. The readers may therefore gain the main concepts of each chapter with as less as possible the need to refer to the concepts of the other chapters. Readers may hence start to read one or more chapters of the book for their own interests.

Method of Presentation

The scope of each chapter is clearly outlined and the governing equations are derived with an adequate explanation of the procedures. The covered topics are logically and completely presented without unnecessary overemphasis. The topics are presented in a book form rather than in the style of a handbook. Tables, charts, equations, and references are used in abundance. Proofs and derivations are emphasized in such a way that they can be straightforwardly followed by the readers with fundamental knowledge of engineering science and university physics. The physical model and final results provided in the chapters are accompanied with necessary illustrations and interpretations. Specific information that is required in carrying out the detailed theoretical concepts and modeling processes has been stressed.

Prerequisites

This book is primarily intended for researchers, engineers, and graduate students, so the assumption is that the readers are familiar with the fundamentals of dynamics, calculus, and differential equations, as well as a basic knowledge of linear algebra and numerical methods. The presented topics are given in a way to establish as conceptual framework that enables the readers to pursue further advances in the field. Although the governing equations and modeling methodologies will be derived with adequate explanations of the procedures, it is assumed that the readers have a working knowledge of dynamics, university mathematics, and physics together with theory of linear elasticity.

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