

# Preface

This book follows the same concept of the first two volumes and is based on the ASME 2013 and 2012 Congress in the track of Dynamics Systems and Control, Optimal Approaches in Nonlinear Dynamics, which were organized by the editors. The nonlinear approaches and techniques have been developed since decades ago. The research on nonlinear science and dynamics have brought new insights into our modeling methods of natural and engineering phenomena. Although many of these approaches and techniques have been brought into research and engineering practices, linearization and simplification are still the dominating approaches existing in physics and engineering. Nature is nonlinear in general as the responses of physics and engineering systems are nonlinear. Linearization ends up with simplification, and it damages the original characteristics of the systems. Such simplifications usually lead to inaccuracy, misunderstanding, or even incorrect conclusions. For example, Hooke's law including the generalized Hooke's law is linear and it composes the foundation of linear elasticity and dominates numerous solutions of physical systems and mechanical designs. However, no material is perfectly linear. Any material used in the real world can actually be a nonlinear and complex system, not only due to its material or structure nonlinearity but also due to the inhomogeneous and anisotropy of the materials.

Another challenge facing the scientists and engineers in our time is the generation of the solutions and characterization of the nonlinear systems modeled from the physical systems in reality. It would be greatly beneficial in accurately evaluating the behavior of nonlinear systems and revealing the actual nature of the systems, with utilization of the existing mathematical tools and analytical means, if the analytical solutions of nonlinear systems could be pursued. Due to the nonlinearity and complexity of the nonlinear systems, unfortunately, it is very difficult or impossible to derive the analytical and closed-loop solutions for the systems. In solving or simulating the nonlinear systems, one may have to rely on approximate or numerical methods, which may only provide approximate results for the systems while errors are unavoidable during the processes of generating the approximate results.

Approximation and inaccuracy are the inescapable shadows following the current research and engineering practices involving nonlinearity or nonlinear systems.

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 the present 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.

With the theme of the book, nonlinear approaches and engineering applications: Applied Mechanics, Vibration Control and Numerical Analysis, the book covers interdisciplinary studies on theories and methods of nonlinear science and their applications in complex systems such as those in nonlinear dynamics, vehicle dynamics, rigid body, solid mechanics, safety, visco-elastic mechanics, control engineering, ocean engineering, mechatronic engineering, acoustic engineering, and material science. Examples include: steady-state dynamic analysis of vehicles; rigid body dynamics and Razi acceleration discussion; a deep discussion about piecewise linear vibration isolators and challenges in discovering its time and steady-state determination; active vibration control for axially translation cables to limit their vibrating reactions; a new numerical solution method for ordinary differential equations where other methods fail; visco-elastic materials analysis and determination of their loss tangent; investigation on the frontal human-vehicle impact and re-designing the hood of the car to save pedestrians; a new treatment and analysis of the post-bukling of thin tube structures; study in acoustics of exhaust system to reduce their noise; parametric segmentation of nonlinear structures in image data; prediction and analysis of sea level.

## **Level of the Book**

This book aims at engineers, scientists, researchers, 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 the present book are of specific interest to engineers who are seeking expertise in nonlinear analysis, mathematical modeling of complex systems, optimization of nonlinear systems, non-classical engineering problems, and future of engineering.

The primary audience of this book is the researchers, graduate students and engineers in mechanical engineering, engineering mechanics, electrical engineering, civil engineering, aerospace engineering, ocean engineering, mathematics, and science disciplines. In particular, the book can be used as a book for the graduate students as well as senior undergraduate students to enhance their knowledge by taking a graduate or advanced undergraduate course in the areas of nonlinear science, dynamics and vibration of discrete and continuous system, structure dynamics, and engineering applications of nonlinear science. It can also be utilized as a guide to the readers' fulfilment 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 12 chapters. Each of the chapters covers an independent topic along the line of nonlinear approach and engineering applications of nonlinear science. The main concepts in nonlinear science and engineering applications are explained fully with necessary derivatives in detail. The book and each of the chapters is 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

The present 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 associated with dynamics in engineering and physics, 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.

## Acknowledgements

This book is made available under the close and effective collaborations of all the enthusiastic chapter contributors who have the expertise and experience in various disciplines of nonlinear science and engineering applications. They deserve sincere gratitude for the motivation of creating such book, encouragement in completing the book, scientific and professional attitude in constructing each of the chapters of the book, and the continuous efforts toward improving the quality of the book. Without the collaboration and consistent efforts of the chapter contributors, the completion of this book would have been impossible. What we have at the end is a book that we have every reason to be proud of.

It has been gratifying to work with the staff of Springer-Verlag through the development of this book. The assistance provided by the staff members has been valuable and efficient. We thank Springer-Verlag for their production of an elegant book.

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