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Utkal Mehta · Kishore Bingi · Sahaj Saxena
Editors

Applied Fractional Calculus in Identification and Control

Springer

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This work is dedicated to the following people:

My students, my family, and my friends who have given me continuous motivation and keep the positive energy around me.

—Utkal Mehta

My parents Narasimharao and Sudharani, wife Sai Ramya Sri, daughter Sri Heshika, and brother Subbu for their encouragement, care, love, and support.

—Kishore Bingi

My parents, wife, and daughter for their constant support and encouragement.

—Sahaj Saxena

Preface

The book aims to present new results and benefits of fractional calculus theory. Various identification and control strategies are introduced to verify the practical usage of fractional-order integrodifferential operators. The book is suitable for advanced research or post-graduate students as a reference book or monograph. The latest results are provided with MATLAB codes' support to understand and adopt the fractional calculus to various applications and areas. It is a guide to fractional-order applications with different areas of systems and control such as system identification, energy sector, vehicle control, and multivariable systems.

The initiation of fractional calculus can be dated back to the eighteenth century with theoretical contributions made by well-known mathematicians Leonhard Euler and Joseph-Louis Lagrange. The theory was extended into systematic studies in the early and middle nineteenth century by Joseph Liouville, Bernhard Riemann, and Erik Holmgren. Then, fractional calculus is utilized in control engineering in two of the most fundamental steps, system modeling and controller design. Numerous experiments in various fields of engineering and science are performed to obtain an accurate system model which captures the dynamic behavior of the system being studied. The model's behavior is often dissimilar to the one expected as integer-order models are used with limited capability when modeling systems with memory phenomena. The system's orders would naturally not be fixed integers, but rather arbitrary real numbers, and thus, incorporating fractional calculus would logically allow more accurate modeling of the system behavior. Interesting results have been shown for controller design methods after introducing more generalized control actions of the Laplace operator in the form $s^{\pm\alpha}$ where α is the positive real number, which would allow more robust and flexible control designs to be produced for thorough satisfaction of the controller specifications.

The definitions of the fractional-order integrals and derivatives have been established for generalized functions whereby the fractional operator α can be rational, irrational, or even complex in nature. Computing the αth derivative of these general class of functions is based on certain conditions being fulfilled and can provide a direction to incubate the nature of new research topics.

Our attempt is that this book will be read by new and active researchers, from master to post-doctoral audiences. For this reason, each chapter is prepared with solutions to support simulation tools and MATLAB codes.

With eleven chapters, the book is structured to maintain the sequential flow. Chapter 1 explores the Katugampola fractional integral of a multivariate vector-valued function and further discusses applying the Weyl-Marchaud fractional derivative to the quadratic fractal interpolation function. Chapter 2 focuses on synchronizing a fractional-order stochastic system in a finite-dimensional space. Also, it evaluated its time reaction and stochastic chaotic behaviors. Chapters 3 and 4 present the merits of fractional-order comb filter for power-line interference rejection and the practical possibility to implement the tuned notch filter. The fractional-order controller design using the internal model control-based strategy has been proposed in Chap. 5 for the integrating processes and in Chap. 6 for the processes having first-order plus time-delay characteristics. Special attention is paid to the tuning processes of fractional-order controllers based on stability margins. The development of a hybrid ILC with the fractional-order predictive PI for time-delay processes is presented in Chap. 7. Chapter 8 designs the robust fractional-order model predictive controller for the DC motor's speed control. Various fractional-order controllers are studied for interconnected multiple source power systems. It shows a fractional integrator to upsurge the flexibility in control. The real-time verification of the fractional-order PI on the quadrotor aircraft makes an interesting outcome in the thematic area. The book ends with last Chap. 11 which focuses on the design of optimum fractional-order PID controller for active suspension control of quarter car model.

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