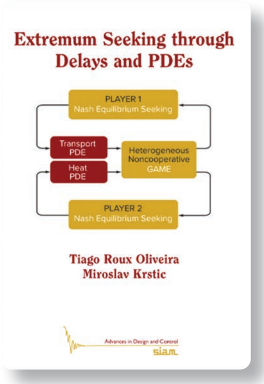
IEEE Control Systems welcomes suggestions for books to be reviewed in this column. Please contact either Scott R. Ploen, Hong Yue, or Thomas Schön, associate editors for book eviews.



SIAM, 2023,
ISBN: 978-1-61197-734-9,
470 pages, US$119.00.

EXTREMUM SEEKING THROUGH DELAYS AND PDEs

by TIAGO ROUX OLIVEIRA and MIROSLAV KRSTIC

Reviewed by Mouhacine Benosman

INTRODUCTION

Extremum seeking control (ESC) is a model-free data-driven learning control framework based on designing a feedback system aimed at optimizing a static or dynamic cost function. As far as I am aware, ESC was first proposed in France in 1922 in the context of railway electrical voltage regulation [1]. However, it was not until about eight decades later that a rigorous theoretical framework was introduced [2] to analyze the convergence of ESC for static maps and dynamical maps described by ordinary differential equations (ODEs). The seminal work [2] was then followed by extending ESC to a wider class of systems, including stochastic systems [3], multiagent systems [4], and hybrid systems [5]. Research in this area culminated in a series of exceptional books on this topic [6], [7], [8].

All of these works focused on systems modeled by ODEs or their extension to differential inclusions. However, real-world applications are often modeled by partial differential equations (PDEs). This class of models includes systems with delays, which are ubiquitous in real life, and continuous spatiotemporal systems, such as fluidic systems.

The field of "classical" model-based control of systems modeled by PDEs is a rich area of study, as demonstrated by the expansive literature on the topic. See [9] and [10] and the references therein for a survey of this area. Yet, in this era of abundant data and increasingly accessible computer power, there is a shift toward more data-driven learning control paradigms, such as ESC. To this end, in the preface, the authors ask: "Why limit the use and the theoretical advances of ESC to ODE systems?" The answer to this question is that extending the theory beyond systems described by ODEs has been difficult because of the extreme technical difficulties inherent in dealing with convergence and stability guarantees of data-driven control for infinite-dimensional systems. However, the authors of this book were able to overcome this challenge, and this book is the culmination of their research program.

CONTENTS

I have to say that I cannot compare this book to another book from the literature simply because there is no other book that covers this topic of data-driven learning control for infinite- dimensional systems. Over my 20-year involvement with control theory and its applications, I have read many books on ODE/PDE model-based control and ESC of ODEs, but I am unaware of any book that blends the two topics so seamlessly and clearly. Indeed, the book starts with a detailed review of the main concepts of ESC for finite-dimensional systems modeled by ODEs. Chapter 1 contains a clear presentation of dither-based ESC gradient algorithms and Newton algorithms, together with their stability analysis. This introductory chapter also covers the concept of Nash equilibrium seeking for noncooperative games. The remainder of this book is dedicated to the study of infinite-dimensional systems and is broken up into three main parts: Part I covers systems with delays, Part II deals with systems modeled by PDEs, and Part III studies systems modeled by noncooperative games. Each part provides an extensive treatment of single-input and multi-input systems with a focus on deterministic, stochastic, gradient-based, and Newton-based ESC algorithms. Another remarkable feature of this book is the many application examples included, ranging from traffic congestion control to source-seeking applications.

The clarity of the writing and the mathematical derivations are of the highest quality, and I feel that anyone with a background in traditional ODE-based control theory should be able to follow the flow of this textbook with ease. This makes the book a gold mine of information for researchers in the field of data-driven control of infinite-dimensional systems and for control systems engineers and practitioners who deal with systems modeled by systems with delays.

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SUMMARY

This book is a truly unique and remarkable work, not only because of its clear exposition and rigorous treatment of the material, but because of its relevance in this era of data-driven learning methods. The authors have put great effort into writing a book that makes this difficult subject as accessible as possible. In summary, I believe this book will become the standard reference in this area for many years to come.

REVIEWER INFORMATION

Mouhacine Benosman (m_benosman@ieee.org) earned his Ph.D. degree in applied mathematics from École Centrale de Nantes, France. He worked at Reims University (France), the University of Strathclyde (Scotland), the National University of Singapore, and Mitsubishi Electric Research Laboratories before joining Amazon Robotics in Cambridge, MA, USA. His research interests include nonlinear robust and fault-tolerant control, multiagent control with applications to robotics, estimation and control of PDEs with applications to thermo-fluid models, learning-based adaptive control for nonlinear systems, control-theory-based optimization algorithms, and physics-informed machine learning. He was an associate editor of *Journal of Optimization Theory and Applications* and *IEEE Control Systems Letters* and a senior editor of *International Journal of Adaptive Control and Signal Processing*.

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BOOK ANNOUNCEMENTS

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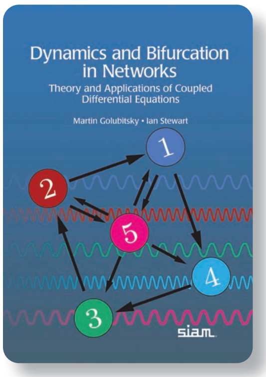

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ISBN: 978-1-61197-732-5,
870 pages, US$129.00.

DYNAMICS AND BIFURCATION IN NETWORKS: THEORY AND APPLICATIONS OF COUPLED DIFFERENTIAL EQUATIONS

by M. GOLUBITSKY and I. STEWART

In recent years, there has been increased interest in network-based modeling in many branches of science. This book attempts to synthesize the common features of these models and aims to provide a general framework analogous to the modern theory of nonlinear dynamical systems. How networks lead to behavior not typical in a general dynamical system and how the architecture and symmetry of the network influence this behavior are the book's main themes. Networks, along with their associated class of "admissible" ordinary differential equations, are defined as a directed graph whose nodes represent component dynamical systems and whose arrows represent couplings between them. This book discusses applications of this formalism to various areas of science, including gene regulatory networks, animal locomotion, decision-making, homeostasis, binocular rivalry, and visual illusions.

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