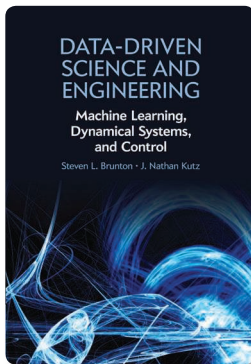


IEEE Control Systems welcomes suggestions for books to be reviewed in this column. Please contact either Scott R. Ploen, Hong Yue, or Thomas Schön, associate editors for book reviews.



DATA-DRIVEN SCIENCE AND ENGINEERING: MACHINE LEARNING, DYNAMICAL SYSTEMS, AND CONTROL

by STEVEN L. BRUNTON
and J. NATHAN KUTZ

Reviewed by Dirk M. Luchtenburg

Cambridge University Press, 2020,
ISBN: 978-1-108-42209-3,
492 pages, US\$64.99.

This book is an accessible and comprehensive introduction to the field of data-driven science and engineering. It is unique in the sense that it brings together interdisciplinary concepts from machine learning, dynamical systems, and feedback control and applies them to physical systems arising in science and engineering. The book provides a broad overview of these concepts and develops tools for data-driven modeling, prediction, and control. Overall, it provides a perfect starting point for an aspiring graduate student or researcher in this field. It can also be used as a text for an advanced undergraduate or graduate course on data-driven model reduction and control. A wealth of accompanying online material (such as Matlab/Python code and a variety of YouTube video lectures) makes the book very suitable for self-study.

CONTENTS

The book is organized into four parts. Part 1 covers dimensionality reduction and transforms. It starts with the “workhorse” of linear algebra, the singular value decomposition (SVD), which sets the stage as a data-tailored reduction tool. The next chapter provides an overview of reduction methods based on Fourier and wavelet transforms. The final chapter of Part 1 provides a detailed discussion of sparsity and compressed sensing.

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Part 2 focuses on machine learning and data analysis. It starts with a basic overview of regression and curve fitting, with an emphasis on overdetermined systems, underdetermined systems, and model selection. After this introduction, the search for patterns in data and their classification are discussed. Here, machine learning algorithms such as K -means clustering and support vector machines are reviewed. Part 2 concludes with an entire chapter on neural networks and deep learning. It includes a nice application of a neural network that learns the dynamics of a Lorenz system.

Part 3 is devoted to dynamics and control. Topics include cutting-edge research topics such as the recently developed dynamic mode decomposition and the sparse identification of nonlinear dynamics algorithms. Classic concepts from control theory (including the linear quadratic regulator, Kalman filter, and balanced model reduction) are also covered. The final chapter of Part 3 provides an overview of the exciting possibilities of data-driven control.

Part 4 mainly focuses on reduced-order models (ROMs) obtained by the proper orthogonal decomposition (POD) algorithm. The POD is the SVD algorithm applied to partial differential equations (PDEs). It is shown how reduced-order models can be obtained by the projection of a PDE onto a POD basis. Interpolation methods for ROMs (such as Gappy POD and the discrete empirical interpolation method) are also discussed.

SUMMARY

This book is well structured and clearly written. It provides an accessible introduction to the field and includes a balanced combination of classic and state-of-the-art research topics in data-driven engineering and science. A remarkable feature of this book is that (almost) each concept is illustrated with Matlab code examples. It should be noted that this book mainly covers material associated with the research interests of the

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Kishan Baheti running in the Boston Marathon.

to make a poster, go to the route, and cheer him on with the poster when he passed by. I totally miscalculated the time he would show up at the mile-marker where I stood, as he was so much faster than I thought! So, I missed him. I did eventually give the poster to him during my next NSF visit," she says. Her second anecdote is even more precious: "I went to the same mile-marker the next year, only to find out later that he did not run that year. When I met him next, I asked him for the reason. He said that

there was something that happened where his family needed his presence. He said, 'there will always be marathons. But when your family needs you, you need to be there, you know!'"

Anuradha adds, "They say that the typical number of people one meets in life is about 10,000, if you were to add up everyone you interact with in your personal, professional, and social spheres. Of this, perhaps there are a few hundred with whom you have a meaningful interaction, professionally. Of these, perhaps there are but a handful of individuals who leave an indelible mark on you, who inspire you, and who you remember with respect, fondness, and joy. Kishan belongs to this last category for me."

These many professional accomplishments and impacts only capture a partial picture of Kishan Baheti. While he was a brilliant and successful professional, his personal qualities made him a great human being and a friend to many. He was kindhearted and magnanimous. He had deep compassion for fellow human beings. He had a tremendous capacity to see the positive and good in each and every situation, no matter how difficult. He believed in others and helped them believe in themselves. He had that rare quality: wisdom. As a part of the control systems research community, we are all deeply grateful for what we have received from our beloved Kishan. We will miss him sorely and will cherish his memories forever.

May Kishan rest in peace.

Aranya Chakraborty
Anuradha Annaswamy
Pramod Khargonekar
Shankar Sastry
Magnus Egerstedt



» BOOKSHELF (continued from p. 95)

authors and, as such, does not touch on all possible topics. However, this approach has kept the book to a manageable size and also gives the book a clear focus. I believe this book will inspire many researchers and give them a head start in the exciting field of data-driven science and engineering.

REVIEWER INFORMATION

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