BOOK REVIEWS

We have quite a lot of material for you in this issue. Our featured review, by Patrick Fitzpatrick, looks at Philippe Ciarlet's *Linear and Nonlinear Functional Analysis*. To cover both linear and nonlinear theory in one volume is quite an ambitious task; not surprisingly the book is over 800 pages long. Fitzpatrick's positive and informative review includes a good deal of historical information about the origins of functional analysis in the study of differential and integral equations and the calculus of variations.

Nonlinear Physics of Ecosystems is an intriguing title. This is Ehud Meron's account of the mathematics behind the self-organizing vegetation patterns like "tigerbush" that arise naturally in certain ecosystems. Reviewer Donald DeAngelis says, "He gives a masterful treatment of the topic of vegetation self-organization that is more than simply a synthesis of previous work—it pushes the field ahead."

We have one book in my favorite area, numerical linear algebra. Take a look at Martin van Gijzen's review of *Krylov Subspace Methods: Principles and Analysis*, by Liesen and Strakoš. The focus is on optimal Krylov subspace methods and their analysis. Connections to orthogonal polynomials, continued fractions, and quadrature rules are made, and there is a discussion and clarification of the Faber–Manteuffel theorem on the paucity of optimal methods with short recurrences.

In addition we have reviews of a book on molecular dynamics, a monograph on elasticity imaging, a new engineering mathematics text that integrates symbolic computing, and a rather advanced text on numerical methods (especially finite element methods) for nonlinear partial differential equations. We also have active subspace methods for dimension reduction in parameter studies, differential geometry and the shape derivative, and a second look at Dan Gusfield's *ReCombinatorics*. Last but not least we have my review of a picture book.

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The great majority of the book is very well explained, and we learned a lot from it. It was exciting to read about many interesting results that have been published since 2006. The book brings all of this together in a nice way and makes the field much more accessible than if one had to hunt down all the papers individually. Computer scientists will find many interesting problems to work on by reading it.

The overall structure is very clear, especially Chapters 5 to 11, but Chapters 12, 13 and the first half of 14 were also very useful. The start was a bit slow and the last half of Chapter 14 does not seem very useful, but by then we were tired after reading 500 pages of concepts and algorithms!

If you read *ReCombinatorics* you will clearly know a lot more about the ARG than before you started. The focus is almost entirely algorithmic, so you will still need to read additional literature about the probability and statistics of the ARG. Yes, a second book on the ARG is needed!

So, most of our criticism is about what is not covered in the book, which would have made it even longer, and it is already long enough. Gusfield doesn't do second editions as far as we can see, so our suggestions will not change this book, but the topics that are missing include *probability theory:* there is a natural probability measure on ARGs, so many questions can be asked about its occurrence. Almost any concept in this book could be mapped either analytically or by simulation. The field really needs a clear 200–300 page book on this topic, but who can and is willing to write it? Also missing is *statistics:* there is hardly any, aside from a few lower bounds and minARGs for the Kreitman data and one other data set. There is surprising little *enumerative combinatorics*, such as counting ARGs with k recombinations, the size of possible data sets with k recombinations, possible ancestral configurations, etc. Such tables can be very illuminating, and to see that you get the right numbers by checking on paper can be very rewarding. Finally, it would increase the book's value as a classroom text if there were exercises, as in Gusfield's book on computational biology (1997), and there must be many open problems that would be stimulating for readers.

Gusfield avoids several hard complexity proofs by simply referring to the literature. On a few occasions he reduces problems whose solutions we would like to know about, e.g., haplotyping to a graph realization problem, ILP, and some NP-hardness results.

Clearly, a book on the probability theory and statistical use of the ARG would address the needs of researchers with data, but any program implementing the ARG is a programming and algorithmic challenge. Reading *ReCombinatorics* would be a perfect intellectual warm-up.

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Nonlinear Physics of Ecosystems. *By Ehud Meron.* CRC Press, Boca Raton, FL, 2015. $89.98. xiv+344 pp., hardcover. ISBN 978-1-4398-2631-7.

One of the great successes in ecology over the past two decades has been the explaining of many striking patterns of vegetation, such as the regular patterns of "tigerbush" in semi-arid lands. These patterns are self-organizing, resulting from the interaction of water, soil, and vegetation. They can also be elegantly described by mathematics. Until recently descriptions of this work were largely available only in scattered papers, but now this book by Ehud Meron, of Ben-Gurion University of the Negev, provides the growing community of scientists interested in these amazing phenomena with a monograph combining the ecology, physics, and mathematics of the topic. Meron is a physicist who has worked with ecologists on self-organizing patterns for many years. He gives a masterful treatment of the topic of vegetation self-organization that is more than simply a synthesis of previous work—it pushes the field ahead. Readers from the disciplines of ecology, physics, and mathematics will all find this a rewarding book.

The book is divided into three main parts: I. "Overview," II. "Pattern Formation Theory," and III. "Applications to Ecology."

Chapter 2 in Part I is an overview of the basics of pattern-forming systems as dynamic systems. It outlines the various types of instabilities and covers stationary and oscillatory, and variational and nonvariational, systems. Chapter 3 reviews spatial ecology and the types of vegetation processes and patterns occurring in arid ecosystems. Chapter 4 is an overview of both the basic ideas and the methodology of modeling spatial systems. In Part II, Chapter 5 introduces basic methods of analysis. It starts with an excellent review of dimensional analysis, in particular, Buckingham's pi theorem, which deserves to be better known. The author then covers the Swift–Hohenberg and Fitzhugh–Nagumo partial differential equation models, which are basic models of pattern formation. Applications and elaborations of these models appear throughout the rest of the book. Chapter 6 moves on to the amplitude and phase equations, which are used for studying the asymptotic dynamics close to the point of instability, but which incorporate nonlinearities. Then singular perturbation theory is introduced for studying solutions far from the instability point. Chapter 7 covers the basic mechanisms of pattern formation, one of which is the growth of spatially structured modes from a uniform state, leading to stationary patterns, traveling wave patterns, and scale-free patterns. Another mechanism involves bistable (or more generally multistable) uniform states, which can give rise to transient patterns or stable asymptotic patterns. Chapter 8 extends the theory to patterns subjected to external periodic forcing.

In Part III the theory is brought to bear on ecological systems. Chapter 9 describes the various feedbacks between plants and water, both above and below ground, in dryland ecosystems. The three-variable Gilad et al. model is analyzed and compared with other models. Using equations from Chapter 9, in Chapter 10 the author describes the variety of vegetation patterns, periodic and nonperiodic (including scale-free), that can emerge, on flat terrain, hill slopes, and in heterogeneous environments. Chapter 11 examines how small environmental changes can affect both uniform and spatially patterned states, leading to possible regime shifts. This is relevant to the problem of desertification. Chapter 12 extends the treatment from one vegetation type to a plant community, in which self-organization can influence biodiversity through promoting coexistence. In particular, the role of plants as ecological engineers and facilitators is described in the context of dryland ecosystems.

This book is essential reading for all ecologists, physicists, and mathematicians, both students and practitioners alike, interested in the topic of ecological pattern formation or pattern formation in general. It would be excellent for a graduate-level semester course (it is based on such a course at Ben-Gurion University). Although the mathematical development is largely self-contained, it would be best for students to have some background in ordinary and partial differential equations or to supplement study of the book with background material. For simplicity, the ecology of the book focuses solely on vegetation patterns in dryland ecosystems, but the approaches are easily extendable to peatlands and other ecosystems.

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Molecular Dynamics. With Deterministic and Stochastic Numerical Methods. *By Ben Leimkuhler and Charles Matthews.* Springer, Cham, Switzerland, 2015. $79.99. xxii+443 pp., hardcover. ISBN 978-3-319-16374-1.

Molecular dynamics (MD) as a computational problem has only recently attracted the attention of a broader audience of applied mathematicians. This book is an expression of that development, and presents MD from the viewpoint of scientific computing and numerical analysis. It emphasizes the simulation of trajectories, and consequently the major theme of the book is the numerical integration of deterministic and stochastic differential equations rather than the computation of thermodynamic quantities or averages by, for example, Monte Carlo methods. It is not a book from which to learn the physical principles of MD, but it provides a gentle and practical introduc-