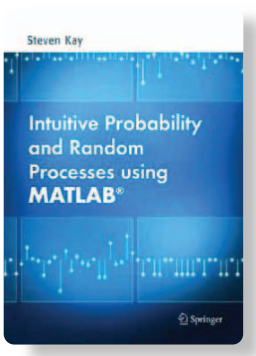
Innovations in Education and Practice

In this issue of *IEEE Control Systems Magazine*, we bring you reviews of three books. The first book, by Kay, presents a highly pedagogical approach to teaching probability theory. The second book, by Wang, Lin, and Lee, is devoted to the use of a feedback relay for identifying points on the Nyquist plot in support of controller design. Finally, the third book, by Codrons, focuses on robust control for process applications.

As usual, I welcome your suggestions for books to be reviewed, as well as volunteers to serve as reviewers.

Scott Ploen
Scott.R.Ploen@jpl.nasa.gov



Springer, 2006,
ISBN 0387241574,
US$59.95, 883 pages.

INTUITIVE PROBABILITY AND RANDOM PROCESSES USING MATLAB

by STEVEN KAY

About a year ago, I was asked to teach a graduate course on probability and random processes at the New Jersey Institute of Technology (NJIT) and to consider adopting the new book by Steven Kay for the course. Knowing the author had already written student-friendly texts on estimation [1] and detection [2], I welcomed the idea. Nonetheless, a careful decision was still necessary before turning my back on standard engineering treatments such as [3] and [4].

Kay's book occupies a unique place in the overcrowded market of textbooks on probability and random processes. The philosophy of the book is defined by the two keywords framing the title on the cover, namely, "Intuitive" and "Matlab." From the first chapter on, it is apparent that the use of intuition is explored through many examples and remarks, with ample use of Matlab simulations. Moreover, the approach is complemented by a gradual exposition of the usual subject matter, wherein entire chapters are devoted to topics that other books such as [1] and [2] typically spend much less time discussing. In particular, the author dedicates one chapter to each of the following fundamental topics: discrete random variables, expected values for discrete random variables, multiple discrete random variables, conditional probability mass functions, and discrete random vectors. The above sequence of topics is then repeated in as many chapters for the case of continuous-time random variables.

TEACHING EXPERIENCES

After using the book for two semesters at NJIT, I reached the conclusion that, due to personal tastes, the style of the book may not appeal to everyone. What is unquestionable is that the book is aimed as a textbook for an undergraduate or first-year graduate course and not as a reference for researchers. In fact, as opposed to standard treatments of this material, the book combines theory and examples without explicitly drawing the line between the two. Furthermore, this book relies less heavily on analysis and does not cover advanced topics such as queuing theory and spectral estimation [5].

As an instructor, I am delighted by the rigorous, yet down-to-earth, introduction of basic concepts that are conventionally taken for granted, such as the relationship between a probabilistic model and computer-based Monte Carlo simulations. I admire the wide variety of carefully thought out examples, and I find the idea of introducing Matlab from the very first chapter rewarding. Notation-wise, the author strikes a good balance between consistency and intuition, even if the notation used in the discussion of sample spaces is unconventional. On the negative side, I soon realized that the highly fragmented presentation requires that the instructor synthesize a careful selection of topics from the myriad examples and remarks to avoid confusion.

In my experience, the initial reaction that students have to this book is puzzlement over its unconventional style, which gives equal weight to both theoretical and practical aspects. However, students soon recognize that the approach taken is ultimately highly pedagogical.

I have also observed that the large variety of applications presented in the book tend to give students the impression that the subject is more complex than it really is. In this sense, a clear summary at the end of each chapter pointing out connections between various topics would be helpful. I have also found that the overview at the beginning of each chapter is often not well received by students. As discussed above, this problem can be overcome by an appropriate synthesis of topics in class by the instructor.

 1066-033X/07/$25.00©2007IEEE

CONCLUSIONS

This new textbook is a breath of fresh air in the market of books devoted to probability and random processes. The book lives up to its ambition of setting a new standard for a modern, computer-based treatment of the subject. Despite the issues discussed above, I fully recommend its use in undergraduate and first-year graduate courses.

REFERENCES

[1] S. Kay, *Fundamentals of Statistical Signal Processing, Volume 1, Estimation Theory*. Englewood Cliffs, NJ: Prentice Hall, 1993.

[2] S. Kay, *Fundamentals of Statistical Signal Processing, Volume 2, Detection Theory*. Englewood Cliffs, NJ: Prentice Hall, 1998.

[3] A. Leon-Garcia, *Probability and Random Processes for Electrical Engineering*, 2nd ed. Reading, MA: Addison-Wesley, 1994.

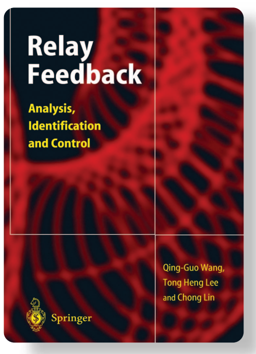
[4] A. Papoulis and U. Pillai, *Probability, Random Variables and Stochastic processes*, 4th ed. New York: McGraw Hill, 2002.

[5] S. Kay, *Modern Spectral Estimation: Theory and Practice*. Englewood Cliffs, NJ: Prentice Hall, 1999.

Osvaldo Simeone

REVIEWER INFORMATION

Osvaldo Simeone is currently an adjunct professor and postdoctoral researcher at the New Jersey Institute of Technology, Newark. He received his Ph.D. in information engineering from Politecnico di Milano, Milan, Italy, in 2005. His current research interests are in information theory and signal processing aspects of wireless systems with emphasis on cooperative communications, MIMO systems, ad hoc wireless networks, cognitive radio, and distributed synchronization



Springer, 2003,
ISBN 978-1852336509,
US$171, 385 pages.

RELAY FEEDBACK: ANALYSIS, IDENTIFICATION AND CONTROL

by Q.-G. Wang, C. Lin, and T.H. Lee

Oscillation is a fundamental property of many technological systems. Two essential components for structurally sustainable oscillation are nonlinearity and feedback. A simple example of a system that generates a periodic signal consists of a relay in feedback with a dynamical system. Since such systems are easy to implement with analog or digital devices, they have been widely used in many applications for more than a century. Analysis of relay feedback systems is therefore a classical topic in control theory. Early work was motivated by relays in electromechanical systems and simple models for dry friction. The classical textbook [1] discusses phase-plane analysis illustrated by several examples.

Self-oscillating adaptive controllers based on relay feedback were developed in the 1960s. More recent applications include Σ-Δ modulators for analog-to-digital conversion, power electronic dc-dc converters, and various control systems such as variable structure control and hybrid control. In 1984, an *auto-tuner* for automatically tuning proportionl-integral-differential (PID) controllers through a relay feedback experiment was considered in [2] and subsequently tested in several industrial applications [3], [4]. This technique triggered substantial efforts in developing practical experiments and identification methods for tuning low-order control laws as well as interest in the analysis of relay feedback systems [5].

A linear system with relay feedback can be described as

$$\dot{x} = Ax + Bu, \tag{1}$$

$$y = Cx, \tag{2}$$

$$u = -\operatorname{sgn} y, \tag{3}$$

where x is an n-dimensional vector, u and y are scalars, and A, B, and C are constant matrices. The relay is modeled as

$$\operatorname{sgn} y = \begin{cases} 1, & y > 0, \\ -1, & y < 0. \end{cases}$$

Since the sign function is discontinuous at $y = 0$, existence of solutions does not follow from the theory of ordinary differential equations. Instead, we rely on an abstract representation of (1)–(3) given by the differential inclusion

$$\dot{x} \in F(x),$$

where the set-valued right-hand side is

$$F(x) = \begin{cases} Ax - B, & Cx > 0, \\ Ax + B[-1, 1], & Cx = 0, \\ Ax + B, & Cx < 0. \end{cases}$$

The interpretation of $F(x)$ is that when x belongs to the switching plane $\{x : Cx = 0\}$, the time derivative of x can take any value in the set $\{Ax + Bu : \ u \in [-1, 1]\}$. The particular choice of $\dot{x}$ is made in such a way that the solution $x : [0, \infty) \to \mathbb{R}^n$ has some desirable property, such as piecewise-continuous differentiability. There is an extensive literature on the relation between solutions of differential equations with discontinuous right-hand sides and their corresponding differential inclusions. A classical reference on these generalized solutions is [6].

http://www.springer.com/978-0-387-24157-9

Intuitive Probability and Random Processes using MATLAB®
Kay, S.
2006, XVIII, 834 p. 294 illus., Hardcover
ISBN: 978-0-387-24157-9