Generally the methods presented are well documented by supporting references. This aggregation alerts the user to viable schemes. The text, in contrast, preoccupies itself with orderly exposition at the expense of potential utility. Application engineers today, and for the forseeable future, will be carrying out realizations digitally. The need should be better addressed. Succinct presentations in the first, second, and fourth chapters do not make clear the uses of interface between the continuous and the discrete for analysis purposes. No mention is made of pole-zero mapping, a convenient digitization procedure. The bilinear transformation is set forth without alerting the user to its frequency warping nature and procedure for corrective prewarping as outlined in Ogata (1987). In total, with programmable controllers available as shelf items*, greater emphasis on techniques associated with digital control implementation would be appropriate.

Almost every method is set forth with an associated CAD (computer aided design) facility. The facility presents a proven algorithm appropriate for a personal computer supporting BASIC. The inclusion of such algorithms is an attractive and worthwhile feature. The author could have gone a step further. In many cases the designer may find it more expedient and economical to purchase commercial software packages. A number of these are available for IBM compatible PCs, for example, from HR-Controls, Hunter Research, Cupertino, California and PC-MATLAB, The Maths Works, Inc., Sherbon, Massachusetts.

The manual does little toward detailing difficulties the user is likely to incur in his translation of methods from theory to practice. Optimal control with quadratic performance index is a case in point. Rosenbrock and McMorran (1971) write that "optimal carries the suggestion . . . of desirable, but this need not be the case" and expound upon these properties. Franklin and Powell (1980) introduce their chapter on multivariable and optimal control with decoupling. It is stated there that the first step in design should attempt to achieve equivalent multiple single-input/output models or decouple the control or estimator.

A second noteworthy case concerns the realization of a controller by forward rectangular integration. The ease with which this method can be understood and applied renders it a plausible candidate for selection. Yet it is known that for long sampling times, this technique transforms portions of the left-half s-plane to unstable regions of the z-plane. Mention is made of neither attribute nor method.

In his concluding assessments, the reviewer finds the manual's contents generally comprehensive. The omission of procedures for dealing with common nonlinearities is noted. Franklin *et al.* (1986) discuss extensions of the root locus to address these situations.

Examples are usually plentiful, and, where appropriate, cite the similarities resulting from diverse approaches. However, they often fail to excite the reader to realism. They illustrate the method cited, but are not augmented to include pertinent experience. Thus guidance is afforded toward the "how" rather than the "when".

Over the last decade the developing theme of control system design has centered about sensitivity analysis. Through those developments, core design issues of disturbance and noise, plant parameter variations and unmodeled dynamics are catagorized under the general topic of robustness (Åström and Wittenmark, 1984). These issues form the overriding design philosophy to be achieved through select methods. Parallelism in a manual is highly desirable. The user is given little direction in these aspects. Finally, the reviewer suggests that insufficient general emphasis exists for topics of parameter identification and adaptive control. References on self-tuning regulators can be found in Åström and Wittenmark (1984). Methods of identification are presented but not well underscored by examples. Adaptation, which represents the state-of-the-art and can be accommodated by present day hardware, is not covered.

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About the reviewer

Louis Wozniak was born in Rome, Italy in 1938. He received the B.S. degree in mechanical engineering and the Ph.D. in electrical engineering from the University of Illinois. Since his doctoral dissertation on "Hydroelectric System Analysis and Speed Control Optimization", he has offered 20 years of consulting service to the Woodward Governor Company in hydro control, and has recently developed a microprocessor-based hydrogenerator governor for the Bureau of Reclamation of the United States Department of Interior. Dr Wozniak is a professional engineer and Associate Professor with the Department of General Engineering at the University of Illinois, teaching applied digital controls.

* As for example, the PC-1000 Multivariable System Controller, Systolic Systems, San Jose, California, and the MAX-100 Real-Time Control and Data Acquisition Processor, Matrix-X, Palo Alto, California.

Control Systems Modeling and Analysis*

Gerard Voland

Reviewer: J. VAN AMERONGEN
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THE BOOK *Control Systems Modeling and Analysis* by Gerard Voland, has been written "for use by those with limited familiarity with the mathematical tools and techniques used in control systems analysis and, indeed, in engineering". The result is an introductory text which can certainly be useful for the author's target group of undergraduate students.

This review will start with a description of the contents of

* *Control Systems Modeling and Analysis* by G. Voland. Prentice-Hall International, U.K. (1986). 226 pp. U.S. $52.35.

the book and the relative importance of the various subjects according to their length. Secondly the didactic approach will be discussed, as it is one of the strong points of the book. Finally, the strong and weak points of the book will be summarized.

The main text is divided into nine chapters. Chapter 1, with a length of 10 pages, begins by providing some historical background information about the development of control engineering and describes the main purposes of control systems design: accuracy and stability. The need for systems modeling, in so far as it is related to these two aims, is explained. Chapter 2 (35 pages) treats differential equations and their solutions. The D-operator is introduced as an abridged notation for d/dt. Chapter 3 (27 pages) continues by solving differential equations by means of Laplace transforms. Up to this point, this is fairly standard material.

Chapter 4 (34 pages) describes numerical approximation methods for obtaining the roots of a polynomial (such as Newton–Raphson, successive approximations and *regula falsi*) as well as numerical integration algorithms (Euler and Runge–Kutta). The text is illustrated by sample programs in Fortran. I would have preferred the use of differential equations of t (instead of the more abstract x), as this would have linked up better with the chapter on Laplace transforms. The sample programs deal with solving the roots of a polynomial, and unfortunately not with numerical integration methods. Although some reference is made to standard packages such as CSMP, DYNAMO and TUTSIM, greater attention to these packages would have increased the value of this chapter. It may be expected that these and other packages will be used extensively in the near future. Such packages enable students to gain much more experience than by writing their own programs.

Chapter 5 (11 pages) introduces the concept of transfer functions and block diagrams. The multiplication symbol introduced here could better have been omitted, as it is not used in the rest of the book. Moreover, its similarity to a summation symbol could be the source of some misunderstanding.

A basic requirement for the use of block diagrams and standard block diagram algebra is either that the various blocks may not influence each other or that this influence is taken into account. That this is not even mentioned is an unfortunate omission.

Chapter 6, "System Analysis", with a total length of 62 pages, forms the heart of the book. It describes the behavior of zeroth-order, first-order and second-order systems, and illustrates them by examples of systems consisting of mechanical elements. The various system components, such as inertia (capacitive storage), spring (inductive storage) and damper (energy dissipation) are systematically discussed and the analogies to electrical and fluid systems are given and illustrated by various examples. One of the examples is selected to illustrate a Fortran program which analytically computes the step response and the settling time of a second-order system.

Chapter 7 (32 pages) discusses control systems. Accuracy and steady-state errors are described and basic control actions such as proportional, derivative and integral control actions are intuitively introduced. Stability is treated in Chapter 8 (24 pages). The method of Routh–Hurwitz and the root-locus method are described. As most students have some difficulties in applying the root-locus method, some more examples would have been useful here.

Chapter 9 describes in 12 (!) pages "Alternative Modeling and Identification Schemes" such as frequency response, sampled data systems and the z-transform, system compensation, non-linearities and modern control theory and state-space modeling.

Four appendices (9 pages) on "Complex Variables", "Integration by Parts", "Method of Partial Fractions" and "Bond Graphing as a Mode of Technical Communication" complete the book. The last appendix, a reprint from an article, is too short to be useful in this book.

From this overview it can be concluded that several parts of the text are very introductory. The basic material, differential equations, Laplace transforms and mathematical models of the above-mentioned base elements, has been discussed thoroughly, however. Many references are provided for readers who want to know more about certain subjects. The contents of the book are not revolutionary; the author borrows most of the examples from others. Nor is it a reference book for those who have to solve a practical control problem. This was apparently not the aim of the author, who wanted first of all to write a textbook which does not go beyond the material used in an undergraduate course. As such, it can be a useful textbook for students without much background in differential equations.

The book has a didactic approach which is not often seen in textbooks of this kind. Each chapter starts with a clear formulation of the learning objectives of that chapter. After a systematic treatment of the various subjects, a review summarizes the main results. Throughout the text, important formulas which should be learned by the student are emphasized by placing them in a box. Each chapter ends with a great number of exercises. These exercises enable the student to verify whether the learning objectives have been realized by studying the text. Unfortunately, the concept of feedback has not been applied to the exercises. Answers, or more elaborated solutions to the exercises, are missing completely. Therefore, the students cannot check whether their answers are correct or not. This makes the book less valuable for self-study outside a course. Apart from this, the book's didactic approach is certainly one of its strong points.

The poor quality of the figures is quite deserving of criticism. The time responses, in particular, lack some essential properties of the systems they should describe (for instance, in none of the figures is the slope of the step response of a second-order system equal to zero at $t = 0$). Especially in a book which gives several numerical examples of how to compute a system's time response, good originals should be the starting point of the illustrator. Moreover, the block diagrams are not always easy to read. A transfer function in a block diagram should be given as:

$$\frac{K_T}{LJs^2 + (RJ + aL)s + (aR + K_e K_T)}$$

and not as:

$$K_T[LJs^2 + (RJ + aL)s + (aR + K_e K_T)]^{-1}.$$

The order of the material is not always logical. In the chapter on "Systems Analysis", a management–production system (taken from Wilcox and Dorf) is analyzed with respect to its steady-state errors for various input signals, and illustrated by a computer program. Yet, the formulas which are used in this example are introduced and explained for the first time in the next section. Even more confusing are the errors in the drawing (an s missing in the feedback) as well as in the text (where a proportional controller is suggested instead of the integral controller which is used in the drawing and the results). These make the example impossible to understand when the original (e.g. Dorf, 1980) is not available.

Many examples in the book have been derived from Dorf (1974). However, the book as a whole cannot be compared with Dorf. The latter goes into much more detail about the various subjects and is also more useful as a reference book. Another book which gives a more extensive introduction to system engineering is *Introductory System Engineering* by Truxal (1972). However, these two books require the reader to have more of a mathematical background than Voland's book does.

To summarize the foregoing in the following conclusions:

—The book is aimed at students without much background in differential equations or the modeling of physical systems. It seems most suitable for those students who do not plan to continue with more advanced courses on systems and control, but still have to know something about the subject.

—It is primarily a textbook which could be used as lecture notes for an introductory course on the modeling of systems and the use of transfer functions.

—From a didactic point of view, the book is quite unique.

Each chapter starts by clearly stating the learning objectives. At the end of the chapter the main subjects are summarized. Important formulas are emphasized by putting them in a box.
—Numerical methods get some attention. Several examples are illustrated by numerical solutions. Some more attention to commercially available standard packages would increase the value of the text. More emphasis on numerical integration methods would also be preferred.
—There are plenty of exercises. Unfortunately, there is no feedback on these exercises. Without such help, a student cannot test whether the material of a chapter has been sufficiently studied or not.
—The drawings, especially the time responses, are of a poor quality.

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About the reviewer

Job van Amerongen studied electrical engineering at Delft University of Technology, where he obtained his Master's Degree in 1971. From 1971 to 1973 he worked with the Royal Netherlands Navy. From 1973 to 1987 he was a scientific staff member at the Control Laboratory of the Electrical Engineering Department of Delft University of Technology. In 1982 he obtained a Ph.D. degree with a thesis on "Adaptive steering of ships". Presently, he is Professor in Control Engineering in the Faculty of Electrical Engineering at Twente University. His research interests are applications of modern control systems, especially in the field of ship steering. He is author and co-author of a great number of papers on adaptive control and ship steering. As the main author and editor he made a course on "Introductory systems engineering" for the Dutch Open University.

Optimal Estimation with an Introduction to Stochastic Control Theory*

Frank L. Lewis

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MORE THAN A DOZEN books have been written within the last 25 years on state estimation and stochastic control, each of them treating these subjects from a more-or-less different viewpoint with respect to theoretical foundations, application-oriented examples, algorithmic developments or computational aspects. The grade of abstraction varies within a wide spectrum, including measure theoretic based stochastics, Ito-calculus for stochastic differential equations, functional analytic convergence proofs, or merely basic foundations of linear algebra. Accordingly, a large variety of different professional groups are addressed: from mathematicians and scientists in research and teaching to engineers in industrial development and application. Generally speaking, all of them are well served by the existing literature. Therefore an interested reader has to ask about the usefulness of an additional offer with this book by F. L. Lewis.

To summarize the answer: this is an extremely well written monograph for all those who enter the fascinating area of stochastic systems. This statement can be justified for many reasons. The first, and most important one, and this is missing in many comparable works, is the clear substantiation of the need of estimation by carefully chosen motivating examples, which are not only taken from aerospace applications like radar tracking, aircraft control, flutter analysis, vibration isolation, and orbit determination, but also from electrical engineering, mechanical engineering and bioecological systems. These motivating examples are interrelated in a balanced way with low-dimensional (often scalar) analytic examples by which the reader is pedagogically lead step by step through the developed formalism and the corresponding algorithms. A second aspect of the work is its comprehensiveness. Every aspect of estimation is covered in its seven chapters, whereby the author managed to remain below 400 pages by moving a lot of results into the exercise and problem area. To elaborate these results the reader is didactically and carefully guided by the problem statements together with hints to the analogies with prior developed results. A further aspect for recommendation is the inclusion of sketches of computer implementations of the filter equations for important applications. A careful mechanization of the filter is the backbone of any numerical implementation both of the real time application and the inherent tendency to numerical instabilities. Although the author does not claim to present the most sophisticated algorithms (reference is given to the relevant literature), his intention to convey a practical intuitive feeling for the estimation concepts is successfully achieved.

The book is intended for use in a graduate course on stochastic control; likewise it may serve as a reference for the engineer in practice. A background in probability theory and linear systems representation in both state space and frequency domain is assumed (including linear algebra; the appendix is deceiving as being no compensation for the necessary basic knowledge). The mathematical requirements are low. Only few results on filter stability are stated as theorems; and their proofs are only sketched, mathematically. Within the derivation of the extended Kalman filter as an approximation to nonlinear estimation the Landau order symbols are used in a misleading manner. No references are given to numerically stable and efficient solutions of the Lyapunov and Riccati equations, respectively, which play a central role in any filter mechanization. A list of the abbreviations used would be useful, although almost all of them are declared somewhere. But does the author assume that every reader is familiar with the abbreviation "PBH-Test"? For the explanation the user must have at hand Kailaths' *Linear Systems* (1980).

The book starts with a summary of what can be called the classical estimation techniques that were initiated by Gauss and culminated in the works of Wiener and Kolmogorov: mean square estimation, maximum-likelihood estimation, recursive estimation, and Wiener filtering. This summary is not only useful from a historical point of view, but the modern theoretical framework always refers back to these fundamentals in the stationary case in the frequency domain. The reader gains insight into both the classical and modern theory by considering the analogies. Beginning with the second chapter, we are lead to the modern estimation theory which arose in parallel with the development of the state space representation of dynamical systems in the early sixties, initiated especially by Kalman and Bucy. Both theories essentially use the same "language". The formalism

* *Optimal Estimation with an Introduction to Stochastic Control Theory*, by F. L. Lewis. John Wiley, London (1986). 376 pp. £43.20.