Estimation and Control of Systems*

Theodore F. Elbert

Review: H. Nijmeijer, Department of Applied Mathematics, Twente University of Technology, P.O. Box 217, 7500 AE Enschede, The Netherlands.

At the end of the 1950s classical control theory techniques had reached a certain mature stage. Everyone working in electrical engineering has come in touch with names like Nyquist, Bode, Wiener, Kolmogorov, McMillan etc. and has heard of notions like gain and phase margin, root locus, feedback stability and so on. All these names and concepts have had direct appeal to linear system theory.

In the early 1960s an extremely important breakthrough was made by Kalman and later by many other scholars. This revolution, so to speak, centres around the concept of the state of a linear system. Some of the most striking achievements of the introduction of the state concept are the complete solution of the LQ and LQG problems, and the development of a more or less complete linear realization theory, allowing the construction of a minimal state space system for a given transfer matrix. Certainly there are other more recent advantages in the state space theory of linear systems, e.g. the geometric approach advocated by Wonham and others, or contributions to identification and adaptive control theory.

The present book offers a review, Estimation and Control of Systems, is intended as a textbook for students with a background in science or engineering and deals with two main topics, namely control by state feedback and estimation theory for state space models. A sort of implicit assumption is familiarity with the tenets of classical control theory. Next a short description of the contents of the book is given. The first chapter contains a very short introduction of the material of the book. Chapter 2 is concerned with probability and estimation theory. It contains a discussion on random variables, functions of random variables, limit theorems and several basic estimation methods for random and non-random variables. In Chapter 3 a treatment of characterizations and properties of stochastic processes is given. After these two preliminary chapters on probability and statistics the author describes in Chapter 4 the basic tenets of system theory encompassing notions like controllability, observability and stability. Then, in Chapter 5 modal control of linear dynamic systems is discussed. Characteristic topics such as pole placement and (reduced order) observer design are treated in some detail, as before both in continuous and discrete time. Chapter 6 is devoted to optimal control of linear systems. Using the ingredients of calculus of variations, the maximum principle is described for and applied to the standard optimal control problems, e.g. minimum time problems and minimum cost problems with or without control variable constraints, again in continuous and discrete time. Next, in Chapter 7 the author returns to the uncertainty in system theory. First several estimation problems (parameter estimation and the estimation of random variables) are treated. The second part of this chapter contains a discussion of elementary filtering and smoothing problems. In the last chapter of the book a short introduction of dynamic programming as a system optimization technique is given. The book ends with four appendices, three dealing with the required preliminaries on matrix theory, optimization theory and the theory of linear differential equations and the last a short comparison of modern and classical control theory. Before ending this summary of the contents of Estimation and Control of Systems it is worth noting a fact that will be much appreciated by many readers. In each chapter some characteristic examples of the contents of the chapter are given and each chapter contains an overwhelming list of (sometimes simple) exercises.

An author writing a textbook to be used in engineering departments is faced with several difficult decisions. First of all — and this is true for almost all textbooks — one has to decide what material should be included and, maybe more important, what should be omitted? Often this has implications on the inclusion or exclusion of the modern (newest) developments in the field. Elbert is not striving to treat the newest directions of research, although some recent advances are included in the references at the end of each chapter. In this respect it is an interesting fact that most of the topics treated by Elbert are also discussed in Kwakernaak and Sivan’s book, which dates back to 1972. In some instances the inclusion of the modern methods of state space theory has reached a certain mature stage. Everyone working in electrical engineering and deals with two main topics, namely control by state feedback and estimation theory for state space models. A sort of implicit assumption is familiarity with the tenets of classical control theory. Next a short description of the contents of the book is given. The first chapter contains a very short introduction of the material of the book. Chapter 2 is concerned with probability and estimation theory. It contains a discussion on random variables, functions of random variables, limit theorems and several basic estimation methods for random and non-random variables. In Chapter 3 a treatment of characterizations and properties of stochastic processes is given. After these two preliminary chapters on probability and statistics the author describes in Chapter 4 the basic tenets of system theory encompassing notions like controllability, observability and stability. Then, in Chapter 5 modal control of linear dynamic systems is discussed. Characteristic topics such as pole placement and (reduced order) observer design are treated in some detail, as before both in continuous and discrete time. Chapter 6 is devoted to optimal control of linear systems. Using the ingredients of calculus of variations, the maximum principle is described for and applied to the standard optimal control problems, e.g. minimum time problems and minimum cost problems with or without control variable constraints, again in continuous and discrete time. Next, in Chapter 7 the author returns to the uncertainty in system theory. First several estimation problems (parameter estimation and the estimation of random variables) are treated. The second part of this chapter contains a discussion of elementary filtering and smoothing problems. In the last chapter of the book a short introduction of dynamic programming as a system optimization technique is given. The book ends with four appendices, three dealing with the required preliminaries on matrix theory, optimization theory and the theory of linear differential equations and the last a short comparison of modern and classical control theory. Before ending this summary of the contents of Estimation and Control of Systems it is worth noting a fact that will be much appreciated by many readers. In each chapter some characteristic examples of the contents of the chapter are given and each chapter contains an overwhelming list of (sometimes simple) exercises.

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Altogether this book, which is very well written, is not too different from several others published in the same area. The explanation of state space concepts is done in a way typical in Anderson, B. D. O. and J. B. Moore (1979). Reference classrooms. The rest is just an addition to the technical literature. Examples and exercises. Maybe they will find their way into classrooms. The rest is just an addition to the technical literature.

References

Safety Systems Reliability
A. E. Green

Reviewer: S. HUMBLE

Reliability and safety are often described as two sides of the same coin. The determination of the safety level of a plant, however, requires more than just a knowledge of the reliability of the system. One must also consider the risk of accidents, whether man-made or natural, and in many plants the probability of the accident occurring will be a combination of some abnormal event and the failure (i.e. unreliability) of the particular preventative system designed to protect the plant at such times. Moreover, one must then try to estimate the risk caused by such accidents which is usually defined as the combination of the probability of such an event, together with its likely consequences.

This definition of safety, and its relationship to, and differences from, normal reliability engineering are very clearly demonstrated in this book. In a clear and straightforward way, it takes the reader through each major technique currently being used to design and assess safety system reliability. The text is written from the author's knowledge of the nuclear power industry. However, the techniques are equally valid for many other types of plant. Moreover, the examples chosen are all successfully aimed at bringing home the salient points and other types of plant. Moreover, the examples chosen are all successfully aimed at bringing home the salient points and reliability theory. However, even here the author stresses the importance of the human factor, which is so often neglected in other texts. In subsequent chapters the author concentrates on the estimation and monitoring of high reliability systems. Here again, unlike many texts there is a necessary change of emphasis. In view of the very high reliabilities required, and hence the rarity of failures, there is a most useful discussion on how one goes about estimating such reliabilities using subjective data as well as reliability data bank.

Not only is his book liberally sprinkled with examples from his own experiences, Dr Green also includes further illustrations in appendices contributed by Mme A. Carnino and Dr Y. Joksimovich which add significantly to the practical flavour of the book. Indeed, it is very much a practical book for the practitioner. Given the limitation of the length of the text, I believe the author should be congratulated on producing a very readable and informative guide to a very difficult subject area. I would recommend it as a good introduction, although I would warn the reader that it should not be the only text he reads on the subject.

About the reviewer
Professor Humble obtained his bachelor's degree and Ph.D. from the University of Durham. He has held teaching research posts at Trinity College, Dublin; University of Colorado; Science Research Council in England; CERN, Geneva; Sheffield City Polytechnic and The Royal Military College of Science, where he is now Professor of Operational Research and Statistics and Chairman of The School of Management and Mathematics. His practical interests lie in systems assessment and reliability engineering.

Control System Synthesis: A Factorization Approach
M. Vidyasagar

Reviewer: M. CALLIER
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The basic problem in recent control system synthesis has been: given a linear time-invariant plant, P (not necessarily stable) and a set of performance specifications, design a compensator, C, such that the resulting plant-compensator feedback system meets the latter. An explosion of results concerning this problem has been generated in the last decade by well known researchers, among which the reviewer cites Youla, Kucera, Desoer, Saeks, Vidyasagar, Francis, Zames and Doyle, to name but a few. The strategy developed has been: (1) find necessary and sufficient conditions such that the plant-compensator feedback system has certain desirable features such as closed loop stability, tracking of a reference signal, rejection of disturbances etc.; (2) parametrize all compensators such that the feedback system meets such feature(s) in such a way that the parametrization is affine in one or two (stable) free parameters; (3) select the parametrer(s) to obtain a compensator such that the closed loop behaviour is


About the reviewer
Henk Nijmeijer received both his university degree and doctorate in mathematics from the University of Groningen, Groningen, The Netherlands in 1979 and 1983, respectively. After spending three years at the Center for Mathematics and Computer Science (CWI), in Amsterdam, he took a research/teaching position at the Department of Applied Mathematics of the Twente University of Technology, Enschede, The Netherlands in 1983. His main research interest lies in the area of nonlinear and linear geometric control theory.