P. J. Antsaklis, Review of: O bservers f or L inear S ystems . By J. O'Reilly. Academic Press, New York, 1983. S IAM R eview , Vol. 28, No. 1, pp. 94-97, March 1986.

generic bifurcation (which is closely related to singularity theory), multiple eigenvalues, problems with $SO(2)$-symmetry and Hopf bifurcation, and bifurcation near orbits of solutions. The basic ideas are illustrated with the study of periodic solutions of autonomous and periodic ordinary differential equations, with semilinear second-order elliptic equations, and with von Kármân's equations for plates and shells.

Unfortunately many who might wish to apply the methods described in this book would find the style uncongenial. Vanderbauwhede begins with the abstract and ends with the concrete, often deferring illuminating motivations. His reliance on modern mathematical terminology occasionally becomes excessive, as when he defines (p. 14) the Fredholm index as an element of **Z**, where **Z** (the set of integers) is not identified. Several more or less standard symbols introduced in the section on functional analysis are not defined. The occasional misprint and linguistic infelicity usually do not obstruct the meaning.

These flaws are mostly superficial (and not unexpected in unedited research notes). I found the book as a whole to be very useful. It has an extensive list of references and a brief index.

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Observers for Linear Systems. By J. O'REILLY. Academic Press, New York, 1983. xii + 246 pp. ISBN 0-12-527780-6. Mathematics in Science and Engineering, Vol. 170.

This monograph on state observers and observer-based controllers for linear systems is intended for graduate students and researchers specializing in control systems. The chapter headings are: Elementary System and Observer Theory; Minimal-Order State Observers; Linear State Function Observers; Dynamical Observer-Based Controllers; Minimum-Time State Reconstruction of Discrete Systems; Observers and Linear Least-Square Estimation for Stochastic Systems; Adaptive Observers; Observer-Based Compensation in the Frequency Domain; Observer-Based Compensation for Polynomial Matrix System Models; Geometric Theory of Observers; and Further Study. These eleven chapters are supplemented by two appendices titled: Some Matrix Theory; and A Little Probability Theory.

The introduction of state-space methods by Kalman in 1960 and the fact that the state, which completely describes the system behavior, is not always available for measurement led to the introduction of the state reconstructor or observer by Luenberger in 1963. The observer generates an estimate of the state, which can then be used, instead of the actual state, to control the system in a feedback control configuration.

There is a vast amount of work in the research literature dealing with the reconstruction of the state, but there is not a single text dedicated to the subject. The aim of this monograph is " to remedy this omission by presenting a comprehensive and unified theory of observers for continuous-time and discrete-time linear systems."

Such a monograph is a timely and welcome addition to the systems and control literature. Over the past twenty years the theory of observers has matured and its importance in the control of systems has been firmly established. The time to present these results in one place and in a comprehensive manner has certainly arrived and this book attempts to do just that; it is an excellent reference book to add to your systems and control library.

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As previously enumerated there are eleven brief chapters in this book, each approximately twenty pages in length; and considering the wide selection of topics covered, some of the chapters are indeed too brief.

The systems of interest are linear and finite-dimensional; a short discussion on state-observers of nonlinear and of infinite-dimensional (linear, delay-differential) systems is also included in the last chapter. Chapter 6 and sections of Chapters 4 and 8 deal with stochastic systems; the rest of this monograph studies observers and observer-based controllers for deterministic linear finite-dimensional (continuous and discrete-time) systems.

When one discusses state observers, the first topics of interest usually are: the full-order full-state observer, the reduced-order full-state observer and the observer of a linear function of the state. These basic topics are appropriately positioned in the first three chapters of this book. Following the prevailing terminology in the literature, the author adopts the term "minimum-order observers" instead of "reduced-order observers." This is a most unfortunate choice because lower order than the "minimum-order" observers can be derived under certain conditions—so the term is misleading. The term "reduced-order observers" describes the situation much more accurately.

The term "minimality" has been used (and abused) in the literature for a long time, and not only in the observer literature at that. The reason for this is quite deeply rooted in our civilization and it has a lot to do with the competitive infrastructure of our society. Minimality is always exciting! The term satisfies bosses, it creates catchy titles for papers and proposals and it usually tends to stop opposing comments, until one comes to the realization that almost anything can be considered optimal, if one is allowed a free hand with the objective function! In short, minimality is a term which has been terribly misused to satisfy one's own purpose, not unlike the terms democracy or religion. The topic here, however, has to do with observers, and the bottom line (another terribly exciting term) is that reduced-order observer is a better term to use than minimal-order observer.

In Chapter 1, the full and reduced-order full-state observers are introduced together with a brief outline of basic system theory concepts. Methods to choose the observer gain and to construct reduced-order observers are discussed in Chapter 2, where the observable canonical form of the system equations is also introduced. In Chapter 3 observers of a linear function of the state are studied, and methods to derive such observers are discussed. When a linear function of the state is to be estimated, one expects to be able to use a lower order observer than one would in the full state reconstruction. Note that such linear functions of the state appear when the state estimate is used to control the plant via linear state feedback. Deriving such minimum-order observers is a difficult problem. It is shown that the problem is equivalent to deriving stable minimal partial realizations (which realize a certain finite sequence of matrices); this suggests a systematic, but unfortunately not very computationally attractive, method to construct minimal-order observers. Decision methods can also be used to derive minimum-order observers of a linear function of the state; and although the procedure requires a finite number of steps, usually this finite number is extremely large.

These first three chapters are well organized, important, and informative but much too brief. This criticism applies to all chapters of this book in different degrees, but the problem is acute in those chapters where the basic structures and the basic methods to design observers are presented: the full-order full-state observer appears for the first time in Chapter 1, as if by magic, as a dynamical system which estimates the state. I was expecting more discussion and deeper coverage of something which is the main theme of this book. The reduced-order observers are introduced in a slightly better fashion; however, the author does not clearly explain what is given in the defining equations, what one should try to find, and how difficult it is to find a solution. And in later chapters when we are asked repeatedly to refer to those defining equations, the mystery still remains. An additional point: for some unknown reason, in Chapter 3 the notation used for the number of inputs and outputs of the system is reversed. In short, I do think that expanded, clearer, and deeper coverage of the fundamental structures and concepts will greatly benefit this book.

There is a great amount of information presented in this monograph; and using the references is necessary to extract the maximum benefit. There are cases, however, where the addition of simple comments could enhance understanding and resolve obvious questions without necessitating that the reader go to the references. Take for example the case of dyadic gain ($V_2 = k\alpha'$) in Chapter 2 (p. 39): Choosing α' appears to be, by reading the text, always possible and quite arbitrary. Only by reading the next theorem very carefully, the reader can perhaps detect that α' should be chosen to make a system single output observable; and this requires that a matrix should be or be made cyclic.

The complete absence of even simple examples is also a drawback; this, combined with the brevity of the chapters and the heavy reliance on using the references for completeness of exposition, puts a real burden on the reader. I do feel that simple examples enhance understanding and are indispensable in a book which is also to be used by "control engineers primarily interested in applications".

Continuing the chapter description, in Chapter 4 the results on observers developed in previous chapters are utilized to design stabilizing feedback controllers, based on the separation principle. The eigenvalue-eigenvector assignment method for linear state feedback is first introduced and the linear quadratic optimal control problem is briefly discussed. It is surprising that the author does not mention the fact that the optimal controller can also be designed via eigenvalue-eigenvector methods. When an observer is utilized to provide a state-estimator to be used together with optimal state feedback, optimality is destroyed. The optimal controller in this case is studied. The last section introduces the transfer function approach to the observer-based controller design. This approach is further discussed in Chapters 8 and 9, and the Nyquist stability criterion is introduced. The zeros of multivariable systems are defined in Chapter 8 and the problems of high gain feedback are discussed; stability robustness is introduced in Chapter 8 and it is also briefly discussed in Chapter 10. Chapters 9 and 10 describe how the polynomial matrix approach and the geometric approach can be used to construct observer-based controllers. Short outlines of the basic concepts of the corresponding theories are also given. These are good chapters although again quite short. Discrete-time systems are studied in Chapter 5, and similar results to the continuous case are derived.

Stochastic systems is the subject of Chapter 6; optimal observers and observer-based controllers are studied using a least-squares approach. Unfortunately, a description of the Kalman–Bucy filter is missing; this is an omission in an otherwise well-written chapter.

Adaptive observers are discussed in Chapter 7. The aim of an adaptive observer is to estimate simultaneously both the parameters and the state variables of the system. This chapter is a good introductory exposition of the subject. The problem of linear state feedback control using an adaptive observer is also discussed.

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Each chapter in this book starts with an introduction summarizing its contents and ends with a section on notes and references, where information is given about the references used in the chapter, about additional references, and about extensions of the topics covered together with historical notes. This is an excellent way to organize a chapter. It facilitates reading and makes it easy to identify relevant references for further exploration. One suggestion here is that the author should have included more references in the text than he already has, especially in connection with the main results. In this way the reader does not have to read the whole section on the notes and references to find the source of interest; however, this is a mild inconvenience.

In summary, this monograph is a valuable and timely contribution to the systems and control literature and an excellent reference book to have. It contains a wealth of information and constructive methods, as well as being a good source for references on state observers and observer-based controllers. It covers topics ranging from the well-known, mature topics of full and reduced-order full-state observers, to the more recent research topics of adaptive observers. The main criticism of this work is that the coverage of many topics and especially of the basic ones is too brief. And the required background of the reader in order to fully appreciate the results presented and the difficulties involved must be, as a consequence, quite strong. Clarity of exposition and ease of study could be greatly enhanced by more numerous and more complete explanations and justifications and by deeper coverage of the basic concepts. Simple illustrative examples, completely absent in this work, could help enhance and clarify the material covered.

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Inverse Problems. Edited by D. W. McLAUGHLIN. American Mathematical Society, Providence, RI, 1984. viii + 189 pp. No price given. ISBN 0-8218-1334-X. SIAM-AMS Proceedings, Vol. 14.

Inverse problems often arise in situations in which one wishes to infer information about an inaccessible region. Geophysics provides many instances of such situations because portions of the earth, oceans, and atmosphere cannot be probed from within. Similarly, medicine is another source of inverse problems because of the desirability of diagnosing abnormalities in a noninvading manner. In both of these fields, waves of one sort or another are often used to extend one's reach and to see inside these inaccessible regions. In these cases, the mathematical aspects of the related inverse problems consist of determining the speed of the waves everywhere inside the region of interest from measurements at the surface.

Since closely related inverse problems occur in widely different contexts, the need for workers on various frontiers to get together is even greater than in other disciplines. One such meeting was organized recently by D. W. McLaughlin under the AMS-SIAM auspices. The present book contains the proceedings of this conference.

As a rule, conference proceedings do not make the best-sellers list. They are usually produced under less than ideal conditions and they often contain research which has appeared, or will appear, elsewhere. The present volume is not exempt from these shortcomings. Nevertheless, within these limitations, it provides an excellent window onto the world of inverse problems.

There are fourteen articles arranged under four headings: Geophysical Inverse Problems, Computed Tomography and Inverse Problems in Medicine, Developments in Mathematical Inverse Problems, and Methods of Maximum Information Entropy. The