Book review

Linear systems theory—a structural decomposition approach by B.M. Chen, Z. Lin and Y. Shamash. Copyright Birkhäuser, Boston, 2004, ISBN: 0-8176-3779-6.

1. Overall assessment

As explicitly mentioned in the title, the main goal of this book is to introduce in detail a family of structural decompositions, which are available for (continuous-time or discrete-time, singular or non-singular) linear systems, and to show how these structural decompositions may be fruitfully employed in the solution of some well-known advanced control problems. In particular, the authors concentrate their attention on the following applications of the structural transformations: sensor/actuator selection in order to ensure that the resulting system exhibits desired structural properties, time-scale and eigenstructure assignment via state feedback, and disturbance decoupling via static output feedback.

2. Book content and organization

In detail, the book is organized as follows: Chapter 2 provides some background material regarding vector spaces, matrix theory and several norm definitions and properties. Chapter 3 reviews some results about linear systems, starting from the continuous-time case and briefly mentioning the discrete-time counterpart. In particular, stability property and its characterization, and structural properties, like controllability, observability, stabilizability and detectability, are introduced and characterized. Also, normal rank and left/right invertibility, as well as finite and infinite zeros, are defined, and the effects of state feedback and output injection on these system properties are described.

In Chapter 4, the stability structural decomposition (SSD) and the real Jordan decomposition (RJD), as well as the observability and controllability structural decompositions (OSD and CSD, respectively) and their block diagonal versions (BDOSD and BDCSD, respectively), are illustrated in detail.

The special coordinate basis (SCB) decomposition of proper systems is the object of Chapter 5, where the properties of the SCB decomposition are also investigated. The analogous analysis is carried on for singular systems in Chapter 6.

Chapter 7 investigates in depth how the finite and infinite zero structures, as well as the invertibility structures, of a continuous-time (discrete-time) system are mapped into those of the corresponding discrete-time (continuous-time) system, obtained from the former by means of the bilinear (the inverse bilinear) transformation.

In Chapter 8, the structural decomposition techniques are fruitfully used to obtain, under certain assumptions, well-known and useful factorizations like the minimum-phase/all-pass factorization and the inner–outer factorization.

Given a linear differential state equation, the structural assignment or sensor selection problem is the problem of suitably choosing the output measurement equation in order to ensure that the resulting linear system is endowed with some desired structural properties, like some given finite and infinite zero structure or left/right invertibility. This problem is addressed in Chapter 9, first for the SISO case and later for the more challenging MIMO case.

The asymptotic time scale and eigenstructure assignment (ATEA) via state feedback is addressed in Chapter 10, again by resorting to the structural decompositions presented in the previous chapters. Also, it is shown how this design technique provides, as rather straightforward byproducts, the solutions to three important problems: the standard H_2 and H_∞ problems, and the disturbance decoupling problem.

Similarly, in Chapter 11, structural decomposition techniques are used to solve the disturbance decoupling problem via static output feedback. An overview of the software toolkit, in Chapter 12, concludes the book.

3. Overall and detailed comments

The book provides the reader with a systematic analysis of the various structural decompositions available for linear systems, and of some of their potential applications, which finds, at my knowledge, no counterpart in any other research book available in the literature. So, it undoubtedly represents a key reference for the research in this subject.

The authors pay lot of attention to the algorithmic aspects of the decomposition procedures they illustrate and, indeed, each

algorithm has been encoded in a suitable Matlab procedure, which can be found in the rich toolkit available at the web site http://linearsystemskit.net. Surely, the authors achieve what I believe was their main goal, namely proving the extreme efficiency of the various transformations they propose in reducing the solution of complex research problems to quite elementary tests and algorithmic procedures. The numerous examples appearing in the book efficiently illustrates these procedures.

Despite of the book clarity and good organization, it is my personal opinion that the book content and perspectives make it suitable for a rather selected audience, with a very specific interest in the decomposition techniques and a rather rich background. Indeed, the two introductory chapters (Chapters 2 and 3) provide a very concise survey of the elementary technical results later exploited in the paper, and of the standard results of Linear System Theory. In my opinion, Chapter 2 would have been better located in the Appendix, while Chapter 3 could have been further extended in order to allow the reader to better follow up with the subsequent theoretical developments. In particular, I perceive the first five subsections, from 3.1 to 3.5, as rather standard, while I believe that the second part of the chapter may not belong to the background of the average reader, and hence it could be discussed in more detail.

The final chapters, from Chapter 8 on, address much more advanced control problems without getting too much into the elementary problem ingredients. For this reason, the reader must be already familiar with these subjects in order to fully appreciate the advantages of the proposed techniques. Differently, the reader is obliged to look for different sources in order to get the desired background. In any event, even the most experienced reader eventually faces the problem of encountering some intermediate result which is not explicitly proved in the book, but simply referenced from some other source (either a book or a journal article). So, my suggestion for a second version of the book would be to make the text a little more self-contained, by introducing some tutorial material which would make the book reading smoother.

The algorithmic part of the book, from Chapter 4 to Chapter 7, is very detailed, generally clear and accurate, however, a little repetitive in structure. Due to the nature of the addressed topic, this last drawback is almost unavoidable, and my only suggestion would be to provide more qualitative comments and, when possible, some physical examples, as the authors did in Chapter 9. The lack of clarity occasionally arises from the fact that when dealing with block matrices, the authors not always clarify the block sizes, in particular, when a block is classified as "irrelevant" and hence denoted with a simple $\star$. Also, occasionally the authors make use of concepts that have not been explicitly recalled in the two background sections. This further supports my suggestion to enlarge Chapter 3.

To conclude, I would like to remark that Chapter 7, concerning the structural properties (finite and infinite zero structures, left/right invertibility property....) that are preserved or modified by the bilinear transformations, which allow to move from the continuous-time to the discrete-time case and conversely, is of extreme interest and originality. In the present version of the book, the content of this chapter is not fully exploited later, and this would be a very interesting task to achieve, in my opinion.

Maria Elena Valcher
Dipartimento di Ingegneria dell'Informazione
University di Padova,
via Gradenigo 6/B 35131
Padova, Italy
E-mail address: meme@dei.unipd.it.

About the reviewer
Maria Elena Valcher received the Master Degree (cum laude) in Electronic Engineering in 1991 from the University of Padova (Italy) and the Ph.D. Degree in Systems Engineering in 1995 from the same university. From November 1994 till October 1998 she was Assistant Professor at the University of Padova. From November 1998 till December 2004 she was Associate Professor, first (1998–2001) at the University of Lecce and later (2001–2004) at the University of Padova. From January 2005 she is Full Professor at the University of Padova.
She is author/co-author of about 50 papers appeared on international journals. She was in the Editorial Board of the IEEE Transactions on Automatic Control (1999–2002) and she is currently in the Editorial Boards of Multidimensional Systems and Signal Processing and of Systems and Control Letters. She is an Elected Member of the Board of Governors (2004–2006) and VP for the Member Activities (2006), of the IEEE Control Systems Society.