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BOOK REVIEWS

LINEAR SYSTEMS THEORY: A STRUCTURAL DECOMPOSITION APPROACH, B. M. Chen, Z. Lin, Y. Shamash, Birkhäuser, Boston, 2004, 415pp. ISBN 0-8176-3779-6

The structural and geometric approach is a consolidated means of analysis and synthesis in multivariable linear systems. Introduced in the late 1960s, this approach has received a multiplicity of contributions throughout the following decades, thus giving rise to a complete theory, expounded in the authoritative books [1, 2]. The fundamental objects of this theory (e.g. controlled invariant subspaces, reachability subspaces, conditioned invariant subspaces, etc.) are also extensively treated in recent books for graduate level courses in system theory, like e.g. References [3, 4].

Nonetheless, the research domain of system structure and control is still very active (see e.g. plenary lecture [5] and the references cited therein). In fact, now that the ever increasing complexity of control systems shows as the most challenging research fields those concerning robustness, non-linear systems, failure detection and fault tolerance, hybrid systems, etc., the interest for the structural aspects of systems which are assumed to be exactly described by linear models is still motivated by several reasons. Firstly, basic problems of robust control, like the H_2 control problem and the H_∞ control problem, can be transformed into disturbance decoupling problems. Secondly, fundamental problems of fault detection and isolation can be tackled as unknown-input observation problems. Thirdly, the structural approach provides powerful tools to deal with more general classes of systems, i.e. time-delay systems. Finally, the structural approach directly aims at disclosing the intrinsic properties of the systems under investigation and pointing out possible unavoidable limitations of the control schemes that can be synthesized for those systems on nominal conditions, thus providing a sort of upper bound for the best performance achievable.

The above-mentioned limitations are specifically connected to the concepts of invariant zeros, phase minimality, left invertibility, right invertibility, structure at infinity, relative degree, etc. In order to inspect these properties, different methodologies have been developed, supported by appropriate algorithms. The structural decomposition, which is performed in the state space domain and, generally speaking, aims at finding special representations of the systems where they appear decomposed in subsystems, each of them, along with its interconnections to the others, conveys information on specific properties, is certainly one of the most extensively followed. Well-known contributions are the Morse's canonical form for linear systems [6], the Aling and Schumacher's nine-fold canonical decomposition [7], and the Lebret and Loiseau's generalization to descriptor systems [8]. This context also encompasses the special coordinate basis, which, introduced and mainly developed by Sannuti and Saberi [9], has received substantial contributions also from the first author of the subject of this review, who provided complete and rigorous proofs of some of its key properties [10].

The special coordinate basis (SCB) is the core of this book, whose scope is to present various canonical representations of linear systems and illustrate some recent achievements regarding their employment in feedback control design. Preceded by a brief review of mathematical background materials and linear system theory, the SCB is then introduced step-by-step. First, two structural decompositions are presented for the autonomous system, whose inherent properties solely depend on the dynamic matrix. Secondly, two structural decompositions are, respectively, set forth for the unforced and the unsensed system, whose properties depend on a pair of matrices (the dynamic matrix and the measured output matrix or the dynamic matrix and the control input matrix, respectively). Then, the SCB is introduced for the proper system, whose properties are determined by a matrix triple or a matrix quadruple. Finally, the SCB is extended to descriptor systems, whose properties are defined by matrix quintuples. It is remarkable that the development of the SCB for proper systems presented in the book differs from the original one, devised by Sannuti and Saberi [9], in the presentation of the proofs and the construction of many algorithms: according to Chen [10], each property is rigorously demonstrated; moreover, several iterative steps of the algorithms have been replaced by single-step transformations, which implies an evident simplification.

Once introduced, the various canonical forms are shown to be effective tools for the design of feedback control laws achieving different goals. The problems that are specifically considered are structural assignment via sensor or actuator selection, eigenstructure assignment via state feedback, and disturbance decoupling via static output feedback. All the problems considered, by their nature, must be solved by means of feedback schemes and the effectiveness of the structural decompositions previously introduced is clear. However, the emphasis on feedback control laws instigates the reader's curiosity about any possible utilization of SCB in solving problems that, by their nature, require a feedforward scheme, like, typically, preview control problems, and also about a possible comparison with well-known decompositions of the geometric approach that have already provided the means to solve that kind of problems.

A peculiar feature of the book is that an extensive discussion is dedicated to explain how the structural properties (i.e. finite and infinite zeros, left invertibility and right invertibility, geometric subspaces, etc.) of a continuous-time system are mapped into the properties of the corresponding discrete-time system under the bilinear transformation, and vice versa. This aspect is worth interest due to its close connections to practical implementation issues in sampled-data control system design and digital signal processing. However, it is rarely considered by the, otherwise vast, literature in the field, probably because of a deeply rooted dichotomy between structural analysis, which is mostly considered a theoretical field, and sampled-data control system design, whose links with applications are much more apparent. Indeed, it is a real asset in this book the effort spent by the authors in filling the gap between theoretical and applied issues in structural control. Their accomplishment is to a large extent due to their experience and wide-ranging interests.

In conclusion, the book appears well-written and well-organized. The large number of numerical examples along with the software implementing all the algorithms in the Matlab environment facilitate the reader in getting acquainted with an allegedly obscure but powerful means as the SCB. Moreover, they provide benchmarks for the comparison with other structural approaches and the respective algorithms. Finally, the accurate and up-to-date bibliography makes the book a good reference also for those researchers who are more familiar with the subject.

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