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Book Reviews

System Identification by T. Söderström and P. Stoica.

REVIEWED BY ROLF JOHANSSON[1]

This book on linear system identification contains twelve chapters and two appendices with Chapter 1 (Introduction) devoted to a general motivation by means of application examples from engineering and science.

Chapter 2 (Introductory Examples) contains a presentation of four aspects or factors affecting identification, i.e., the system, the model structure, the identification method and the experimental condition. A traditional but not very clear distinction is here being made between nonparametric methods (transient analysis and correlation analysis) and parametric methods adapted to linear models. Problems of bias and consistency are discussed in a traditional manner and followed by experimental issues in the form of excitation and complications due to feedback control. Chapter 3 (Nonparametric Methods) deals with a short treatment covering transient analysis, frequency (response) analysis, correlation analysis, and spectral analysis.

Chapter 4 (Linear Regression) with a presentation of the least-squares method and the normal equations including statistical and computational aspects as applied to estimation of system parameters. In Chapter 5 (Input Signals) is being characterized what is an appropriate input to a system under investigation. Spectral and statistical properties such as persistency of excitation are covered.

Chapter 6 (Model Parametrizations) contains a classification of various types of discrete-time linear input-output models with a discussion on uniqueness and identifiability. Little attention is given to multivariable systems.

Chapter 7 (Prediction Error Methods) contains a framework aiming to assess identification as a mathematical problem related to the Kolmogorov-Wiener approaches to linear prediction. Statistical properties of least-squares methods and the maximum-likelihood method are treated with some detail for Gaussian noise processes. This chapter appears to be the main chapter of the book.

Chapter 8 (Instrumental Variable Methods) treats a number of modifications to the least-squares method. Several algorithms usually presented in their own right such as the Yule-Walker equations or the Levinson-Durbin algorithm are here considered in the framework of instrumental methods.

Chapter 9 (Recursive Identification Methods) is introduced as a special computational organization of least-squares estimation and the correspondence with the Kalman filter is demonstrated. Several different recursive identification methods are presented. In Chapter 10 (Identification of Systems Operating in Closed Loop) is considered the problems appearing when the system input is generated by a feedback loop.

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In Chapter 11 (Model Validation and Model Structure Determination) is posed questions whether a given model is flexible enough; whether a given model is too complex and what model structure to be chosen. A number of statistical tests for choice of model order among linear models are formulated as statistical problems of hypothesis testing. Most of these tests are based on various properties of the residuals between data and the behavior predicted by the model under consideration. Numerous examples are provided using the pioneering identification package Idpac—a predecessor to much of existing identification software.

Chapter 12 (Some Practical Aspects) is organized around some application issues associated with the identification experiment and data acquisition. Several examples consider problems of data offsets and time-varying trends and nonzero initial conditions using an approach of data filtering prior to the application of the methods of Chapters 7–8. In addition, as several methods based on iterative optimization methods may have problems with local minima, there is a discussion when to expect unique minima of prediction error methods. Several examples are provided using the identification package Idpac.

Appendix A (Some Matrix Results) contains a compact summary of results concerning partitioned matrices, least-squares properties, matrix norms, and Kronecker products. Appendix B (Some Results from Probability Theory and Statistics) contains an account of basic results on the Gaussian distribution and the χ^2-distribution. Also, the Cramér-Rao lower bound and the Kalman filter are reviewed. Finally, references, answers to exercises (but not solutions), author index, and subject index are found in the last pages of the book.

This is a well organized book with introductory examples illustrating relevant problems and motivating further theoretical study. The organization around the concepts of parameter uniqueness and statistical consistency of parameter estimates appears to be another principle of organization.

With some exceptions such as model reduction, state-space models, frequency domain aspects, continuous-time models there is good and coherent coverage of the subject matter within the limits of time-series analysis and linear systems. Clearly, the strong focus on time-series analysis and the restriction to linear systems also impose certain restrictions as to the scope of application.

Furthermore, little and insufficient emphasis is put on problems associated with identification of multivariable systems. This is a weakness in view of the fact that the book is organized around consistency and parameter uniqueness for which generalization to the multivariable case is not straightforward.

Among weak points is the habit to approximate the sample mean $\Sigma_{k=1}^{N} x_k/N$ as $\mathcal{E}\{x_k\}$ to an overabundant degree. Although this habit is possibly based on the notion of the central limit theorem as an approximation theorem, it leaves the reader with some confusion as to the accuracy and validity of remaining calculations.

A comparison to texts [1–4] which appeared prior to the publication of the reviewed book shows that this book is up-to-date in material and references. It can be compared in scope with [1], [3] and [4] although Ljung's book has a stronger emphasis on frequency domain properties and interactive software.

I have successfully used the book as the main textbook in our graduate program in process identification with good experience concerning the students' ability to digest the subject matter. The figures and illustrations are sparse but relevant and contributes to the serious impression of the book. The unified description of many different algorithms, which owes its approach to the "modern" tradition, provides the book with a comprehensive style which makes it suitable for beginning graduate level students. Thus, it can be summarized that this is a good book with its clear focus on time-series analysis and linear systems.

References

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4 Ljung, L., *System Identification—Theory for the User*, Prentice Hall, 1987.

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