Book reviews

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Multivariable Feedback Design

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The monograph surveys modern multivariable feedback theory and design for continuous time systems. It consists of Preface, List of symbols and abbreviations, 8 Chapters, Appendix and Index. Chapter 1 (Single-loop Feedback Design) reviews the analysis and design of single-loop feedback systems assuming the knowledge of linear systems theory concepts such as state-space model, controllable, observable, minimal realization and state feedback. Nyquist stability theorem, fundamental relation in a standard problem and the "shape" of the solution are presented. It includes both "closed-loop" design, in which a desired closed-loop transfer function is somehow established and followed by automatic synthesis of a controller, and "open-loop" design, in which the plant characteristics are explicitly considered. The difficulties caused by the existence of fundamental trade-offs between the conflicting objectives of reducing sensitivity and parameter uncertainty, and filtering out any internally generated noise are explained. The restriction caused by the location of any zeros or poles in the right half-plane on the range of frequencies, over which the use of feedback can be beneficial, is mentioned. Chapter 2 (Poles, Zeros and Stability of Multivariable Feedback Systems) is concerned with establishing stability criteria generalizing the classical Nyquist criterion. In order to do this, transfer function matrices as descriptions of multivariable linear dynamic systems are introduced including their relation to state-space models. Matrix fraction descriptions are presented as alternative representations. The notion of poles and zeros is generalized to multivariable systems by means of the Smith-McMillan form of a transfer function matrix. The concept of "internal stability" is defined, and the generalized Nyquist stability, and generalized inverse Nyquist stability theorems are developed in terms of characteristic loci, i.e. graphs of the eigenvalue functions of a multivariable return ratio. Sufficient conditions for closed-loop stability or instability are presented using Gershgorin bands, along with means of reducing their conservativeness. Chapter 3 (Performance and Robustness of Multivariable Feedback Systems) deals with the analysis of performance and stability robustness of feedback systems in the face of specific disturbances or parameter variations going beyond the notions of gain and phase margins. It presents the result that the use of principal gains, or operator norms of suitably weighted transfer functions as a mathematical tool leads to the conclusion that performance specifications are interchangeable with uncertainty specifications, and the same tools can be used to assess the attainment of both types of specification. A new representation of plant uncertainty is introduced. It can examine a wide variety of both structured and unstructured perturbations. Chapter 4 (Multivariable Design: Nyquist-like Techniques) presents several approaches mostly directly extending the classical Nyquist-like techniques for SISO systems, when each approach ultimately replaces a multivariable problem by a set of SISO problems. These methods are known as the "British school" of multivariable design, and provide the simplest and most easily comprehensible design techniques. The sequential loop-closing approach, the Nyquist-array approach and the characteristic-locus approach require a preliminary decoupling stage, which can be aided by use of the ALIGN algorithm or one of its generalizations, to reduce high-frequency interaction and make subsequent design steps easier. The quantitative feedback theory is presented as an approach which should be considered when a precise specification of both the model uncertainty and permissible closed-loop behaviour is available. This is more complicated, more systematical and more powerful approach than other approaches. Control-structure design known also as the pairing problem solved using the relative-gain array is mentioned. Chapter 5 (Multivariable Design: LQG Methods) presents the general linear quadratic Gaussian problem including its solution and also its restriction yielding a useful method (LQR/LTR) of feedback design. An equivalence of adjusting the various covariance and cost-weighting matrices in the LQG problem with adjusting the trade-off between the principal gains of various closed-loop transfer functions is shown, particularly for the output of a plant when using the LQG/LTR method, and for plants with right half-plane zeros. Chapter 6 (The Youla Parametrization and H_∞ Optimal Control) deals mainly with H_∞ optimal control. Coprime factorizations of multivariable systems are introduced including methods of obtaining their state-space realizations. The Youla parametrization of all stabilizing feedback controllers for a system using these factorizations is introduced. A derivation of the solution of 1-block H_∞ is given, and the Glover-Doyle algorithm is presented for the solution of general H_∞ problems. The Hankel approximation problem is introduced together with its applications in H_∞ optimal control and model approximation. Chapter 7 (Design by Parameter Optimization) presents three methods of optimizing the parameters of a controller for a given system. Edmunds' algorithm solves a specific frequency-domain optimization problem, the method of inequalities and multi-objective optimization are capable of solving general design problems. Chapter 8 (Computer-aided Design) presents some fundamental algorithms from numerical linear algebra. They are nowadays available in software products, but experience has shown that some knowledge of their work is needed when applying them. Some of the available software products are described. Appendix describes Models used in Examples and Exercises. All the examples and exercises have been solved using PC-Matlab, together with *Control System Toolbox* and *Multivariable Frequency Domain Toolbox* (*MFD*). End-of-chapter design exercises are supplied.

The book surveys in a comprehensive and unified way modern multivariable feedback theory and design. It has a character of a clearly written and practical genuine textbook with up-to-date treatment of robustness analysis, extensive use of a flight control problem to illustrate each design technique and details of the algorithms required for multivariable analysis and design.

References

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