PREFACE

Adaptive control systems have been developed considerably during the last 40 years. The aim of this technique is to adjust automatically the controller parameters both in the case of unknown and time-varying process parameters such that a desired degree of the performance index is met. Adaptive control systems are characterised by their ability to tune the controller parameters in real-time from the measurable information in the closed-loop system. Most of the adaptive control schemes are based on the separation of parameter estimation and controller design. This means that the identified parameters are used in the controller as if they were the real values of the unknown parameters, whereas the uncertainty of the estimation is not taken into consideration. This approach according to the certainty-equivalence (CE) principle is mainly used in adaptive control systems still today. Already in 1960 A. Feldbaum indicated that adaptive control systems based on the CE approach are often far away to be optimal. Instead of the CE approach he introduced the principle of adaptive dual control (Feldbaum 1965). Due to numerical difficulties in finding simple recursive solutions for Feldbaum's stochastic optimal adaptive dual control problem, many suboptimal and modified adaptive dual control schemes had been proposed. One of the most efficient approaches under those is given by the bicriterial synthesis method for dual adaptive controllers. This bicriterial approach developed essentially by the authors of this book during the last 10 years and presented in detail herein is appropriate for adaptive control systems of various structures. The main idea of the bicritical approach consists of introducing two cost functions that correspond to the two goals of dual control: (i) the system output should track cautiously the desired reference signal; (ii) the control signal should excite the plant sufficiently for accelerating the parameter estimation process.

The main aim of this book is to show how to improve the performance of various well-known adaptive controllers using the dual effect without complicating the algorithms and also how to implement them in real-time mode. The considered design methods allow improving the synthesis of dual versions of various known adaptive controllers: linear quadratic controllers, model reference controllers, predictive controllers of various kinds, pole-placement controllers with direct and indirect adaptation, controllers based on Lyapunov functions, robust controllers and nonlinear controllers. The modifications to incorporate dual control are realized separately and independently of the main adaptive controller. Therefore, the designed dual control modifications are unified and can easily be introduced in many certainty equivalence adaptive control schemes for performance improvement. The theoretical aspects concerning convergence and comparisons of various controllers are also discussed. Further, the book contains descriptions and the text of several computer programs in the MATLAB/SIMULINK environment for simulation studies and direct implementation of the controllers in real-time, which can be used for many practical control problems.

This book consists of sixteen chapters, each of which is devoted to a specific problem of control theory or its application. Chapter 1 provides a short introduction to the

dual control problem. The fundamentals of adaptive dual control, including the dual control problem considered by A. Feldbaum, its main features and a simple example of a dual control system are presented in Chapter 2. Chapter 3 gives a detailed survey of adaptive dual control methods. The bicriterial synthesis method for dual controllers is introduced in Chapter 4. Chapter 5 provides an analysis of the convergence properties of the adaptive dual version of Generalized Minimum Variance (GMV) controllers. Applications of the bicriterial approach to the design of direct adaptive control systems are described in Chapter 6. In this chapter, also a special cost function is introduced for the optimization of the adaptive control system. Chapter 7 describes the adaptive dual version of the Model Reference Adaptive Control (MRAC) scheme with improved performance. Multivariable systems in state space representation will be considered in Chapter 8. The partial-certainty-equivalence approach and the combination of the bicriterial approach with approximate dual approaches, are also presented in Chapter 8. Chapter 9 deals with the application of the Certainty Equivalence (CE) assumption to the approximation of the nominal output of the system. This provides the basis for further development of the bicriterial approach and the design of the adaptive dual control unit. This general method can be applied to various adaptive control systems with indirect adaptation. Adaptive dual versions of the well known pole-placement and Linear Quadratic Gaussian (LQG) controllers are highlighted in Chapter 10. Chapters 11 and 12 present practical applications of the designed controllers to several real-time computer control problems. Chapter 13 considers the issue of robustness of the adaptive dual controller in its pole-placement version with indirect adaptation. Continuous-time dual control systems appear in Chapter 14. Chapter 15 deals with different real-time dual control schemes for a hydraulic positioning system, using SIMULINK and software for AD/DA converters. General conclusions about the problems, results presented and discussions are offered in Chapter 16.

The organization of the book is intended to be user friendly. Instead reducing the derivation of a novel adaptive dual control law by permanent refering to controller types presented in previous chapters, the development of each new controller is discussed in all important steps such that the reader needs not to jump between different chapters. Thus the presented material is characterized by enough redundancy.

The main part of the results of this book were obtained during the intensive joint research of both authors at the “Control Engineering Lab” in the Faculty of Electrical Engineering at Ruhr-University Bochum, Germany, during the years from 1993 to 2000. Also some very new results concerning the application of the previous results to neural network based “intelligent” control systems have been included. During the preparation of this book we had the helpful support of Mrs. P. Kiesel who typed the manuscript and Mrs. A. Marschall who was responsible for the technical drawings. We would like to thank both of them.

This is the first book that provides a complete exposition on the dual control problem from the inception in the early '60s to the present state of research in this field. This book can be helpful for the design engineers as well as undergraduate, postgraduate and PhD students interested in the field of adaptive real-time control. The reader needs some pre-

liminary knowledge in digital control systems, adaptive control, probability theory and random variables.

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