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A strong analytic mathematical description is the essence of this book, in which Andreas Kugi expounds the important link between modeling and nonlinear control. Mathematical models are derived from physical principles and used as the basis for controller design. The utility of the techniques is demonstrated by applying them to practical problems.

Chapter 1 summarizes the basics of Lyapunov theory, dissipativity, passivity, positive rea lity, and absolute stability. Also discussed are absolute stability and the Popov criterion and port-controlled Hamiltonian systems with and without dissipation. In essence, this chapter encapsulates the theory required for later chapters.

Chapter 2 summarizes the essential results of nonlinear state feedback \( H_2 \) design for affine-input systems, nonlinear state feedback \( H_\infty \) design for affine-input systems, and the passivity-based control concept. Nonlinear state feedback \( H_2 \) design is extended such that an integral part can be systematically included in the controller.

Chapter 3 presents theory for energy-based descriptions of electrical systems, which is an extension of the Brayton-Moser theory. The combination of this energy-based concept with graph theory allows the derivation of the mathematical model of an electrical network in the form of a port-controlled Hamiltonian system with dissipation. The modeling process is demonstrated by a simple terminal model for a power generator and a three-phase system. An example of a laboratory model of the Cuk converter shows how this approach can contribute to the design of a nonlinear \( H_2 \) controller with and without integral term.

Chapter 4 describes finite- and infinite-dimensional mechanical systems that have the structure of a port-controlled Hamiltonian system. Nonlinear \( H_2 \) design, nonlinear \( H_\infty \) design, proportional differential controller design, and disturbance compensation for finite- and infinite-dimensional port-controlled Hamiltonian systems are presented. The various control strategies developed are applied to an infinite-dimensional piezoelectric composite beam structure. Treating actuator and sensor design as an integral part of the control design task helps prevent observation/actuation spillover.

Chapter 5 describes two special types of hydraulic drive systems: a valve-controlled translational piston actuator and a pump-displacement-controlled rotational piston actuator. The mathematical models for the hydraulic drives are presented. A nonlinear controller based on input-output linearization is proposed that requires only measurable quantities. This nonlinear control concept is demonstrated by the hydraulic gap control, the innermost control loop for thickness control in rolling mills. An adaptive controller to compensate periodic disturbances in strip exit thickness is presented. Stability is proved by a passivity-based argument.

This book, which is volume 6 of the Annals of the International Society of Dynamic Games, contains 18 papers presented at the 8th International Symposium on Dynamic Games and Applications, held in Maastricht, The Netherlands, 5-8 July 1998. The book is divided into four major parts.

**Part I, Dynamic Games: Theory,** contains six papers on deterministic games. One of the papers studies a static game; the rest deal with dynamic games (DGs). “On Problems with Information in Some Games: Modeling the Strategies in Some DGs” considers zero-sum, duel-like games in which the players may have either observable or nonobservable information about the game’s history. “A Historical Perspective on Cooperative Differential Games” presents a survey of papers from the late 1960s to about 1990 on the use of cooperative solution concepts in the theory of differential games. “Certainty Equivalent Principle and Minimax Team Problems” studies a class of minimax team problems that are the nonlinear equivalent of the linear \( H_\infty \) control problems. “Evolutionary Processes in Signaling Games: The Impact of Different Learning Schemes” presents an evolutionary approach to two-player, two-type, signaling games. “Mixed Strategies for Hierarchical Zero-Sum Games” studies static noncooperative games with a leader and two followers, which can be expressed as hierarchical saddle-point problems. Finally, “Existence and Uniqueness of Equilibria in Convex Games with Strategies in Hilbert Spaces” proposes an abstract setting to analyze the existence and uniqueness of Nash equilibria for convex games in which the strategies of each player are in separable Hilbert spaces.

**Part II, Stochastic Games (SGs),** includes five papers. “The Existence of Equilibrium Payoffs in Two-Player SGs” considers a two-player, finite-state, finite-action SG with the expected average payoff criterion. “Persistently Good Strategies for Nonleavable SGs with Fi-
finite State Space” shows the existence of persistently ε-optimal strategies for players engaged in a two-person zero-sum nonleavable SG with the lim-sup criterion. “On Stochastic Hybrid Zero-Sum Games with Nonlinear Slow Dynamics” considers a continuous-time nonlinear system with dynamics depending on the evolution of a discrete-time, finite-state, finite-action, zero-sum Markov game with transitions at integer multiples of a parameter ε > 0. “On Multichain Markov Games” studies zero-sum Markov games with Borel state and action spaces and the average cost criterion. The hypotheses allow the state process, a Markov chain, to have several periodic recurrence classes. Finally, “Perturbed Zero-Sum games with Applications to Stochastic and Repeated Games” analyzes asymptotic properties of zero-sum matrix games with payoff matrices Ge, which depend continuously on a parameter ε > 0. Under suitable conditions, the limit of the values and the policies of Ge as ε → 0 are characterized.


Part IV, DGs: Applications, contains three papers. “On Optimal Missile Guidance Upgrades with Dynamic Stackelberg Game Linearizations” investigates the most critical final homing phase of the last few seconds for one intercepting missile (the pursuer) versus one maneuverable ballistic missile (the evader). “Homicidal Chauffeur Game: Computation of Level Sets of the Value Function” studies two differential games with the dynamics of the homicidal chauffeur. The first is the Isaacs homicidal chauffeur differential game, in which a chauffeur or pursuer (P) minimizes the capture time of a pedestrian or evader (E); E’s objective is to avoid capture or to maximize the capture time. The second game is the conic surveillance-evasion game. The dynamics are the same as in the Isaacs problem, but the players have different goals: the evader E wishes to minimize the escape time from a certain detection set, whereas P’s objective is to keep E within the detection set for maximum time. Finally, “The Tragedy of the Commons Modelled by Large Games” introduces a model describing the exploitation of a common renewable resource by a large number of players. The main issues are the existence and properties of equilibria, as well as means to enforce optimality.

**Industrial Control Systems Design**


This broad overview of different advanced control design methods with special focus on practical industrial applications is structured in three parts: 1) Polynomial System Descriptions; 2) State-Space and Frequency Response Description; and 3) Industrial Applications. Parts 1 and 2 are mostly theoretical, even though small practical numerical examples are distributed throughout the text. Various discrete-time control strategies are described, such as $H_2$ or $H_\infty$ optimal control, but also predictive optimal control or quantitative feedback theory (QFT). Part 1 on polynomial methods, mainly following Vladimir Kuèèra’s school initiated in the late 1970s, is significantly more developed than part 2 on state-space methods, which adequately compensates for the large number of newly published books focusing on pure state-space methods. Part 3 is oriented toward industrial applications, showing clearly that a wide range of tools is required to cope with various practical requirements. Based on the author’s vast experience with industrial projects, comprehensive chapters are dedicated to electrical power generation and transmission, metal rolling processes in hot strip mills, marine control systems for roll stabilization and ship positioning, turbofan engine control, and flight control design.

Chapter 1 is a general introduction to advanced industrial control and features an interesting comparison between polynomial techniques and state-space techniques, as well as an original, documented overview of fault-tolerant control systems encompassing fault monitoring and diagnosis, redundancy, control reconfiguration, and multiple model approaches. Chapter 2, the first chapter of part 1, is dedicated to the polynomial solution to scalar (SISO) $H_2$ control, a particular case of which is LQG control. Multiple-degrees-of-freedom $H_\infty$ control is described, and it is shown that feedforward, feedback, and tracking components of the cost function can be tuned independently. Chapter 3 proposes an original extension of chapter 2 to $H_1$ predictive optimal control. After a short review of historical developments of generalized predictive control (GPC), an LQG optimal predictive control is described based on a nested set of polynomial Diophantine equations. Chapter 4 is an extension to multivariable (MIMO) systems of the polynomial $H_1$ optimal control law introduced in chapter 2. In chapter 5, a polynomial approach to $H_\infty$ optimal control
is pursued. The SISO version is first proposed, with feedback tracking and feedforward components, as a counterpart to the $H_2$ SISO control of chapter 2. Then, a single-input, multiple-output (SIMO) version is introduced, with a specific application to power systems in mind. Finally, the $H_\infty$ equivalent of the LQG predictive control law of chapter 3 is presented. Chapter 6, the last chapter in part 1, is devoted to polynomial techniques such as $H_2$ and $H_\infty$ filtering and prediction. $H_2$ estimation is described as a control strategy suitable for stochastic problems, in contrast to $H_\infty$ estimation, which is suitable for robustness problems.

Part 2 of the book, focusing on state-space techniques, opens with chapter 7 on $H_2$ and $H_\infty$ control and filtering. The discourse shows that the solution relies on discrete algebraic Riccati equations, Kalman filters, and the classical separation principle. Predictive optimal control is the topic of chapter 8 and can be viewed as the state-space counterpart of chapter 3. LQG GPC design with a multistep criterion is shown to overcome undesirable stability and robustness properties of the standard GPC. Through terms are then introduced to approximate the fast dynamics between system inputs and outputs. Chapter 9 on QFT techniques, the last chapter of part 2, offers a different perspective of optimal control, allowing direct manipulation of system frequency responses. The discussion shows how QFT can give insight into the previously studied state-space optimal control strategies of part 2.

The third and last part of the book is a collection of four chapters describing industrial applications of the theory developed in the first two parts. Chapter 10 concerns power generation and transmission and demonstrates that the problem of controlling the voltage of a generator can boil down to an $H_2$ or $H_\infty$ SIMO control problem, as studied in chapter 5. Feedback is required to reduce oscillation between power station and network. The design of control for metal processing is the topic of chapter 11, which offers a well-documented survey on existing techniques for multivariable hot strip mill control. After an extensive description of different control problems that can arise (control of interstand tension, flatness, and profile), MIMO state-space $H_\infty$ techniques are applied. Chapter 12 is devoted to marine control systems, more specifically, to fin roll stabilization and robust ship-positioning systems. Finally, chapter 13 offers a perspective on aero-engine and flight control design. The first section on gas turbine control describes the application of MIMO state-space $H_\infty$ techniques to control an axial twin-spool reheated turbofan engine, whereas the second section focuses on a MIMO state-space $H_\infty$ design for a generic canard-delta aircraft configuration.

The book covers a wide range of advanced control strategies with a clear preference for polynomial techniques. As its title suggests, the main strength of the book is its careful description of several industrial applications. Each chapter opens with a comprehensive expert description of an industrial control problem, including a survey on existing techniques and approaches. Extensive numerical results are then provided illustrating how modern control technologies can be applied successfully. In addition, in parts 1 and 2, the theory is systematically illustrated by a remarkable set of small but meaningful numerical examples distributed throughout the text. The examples are meant to bridge the gap between practical industrial concepts and the sometimes too abstract style of control theory textbooks. One disappointing feature is that in part 3, four large chapters on industrial applications cover almost exclusively $H_2$ and $H_\infty$ techniques, whereas parts 1 and 2 are wider in scope, describing predictive control, filtering, estimation, and QFT methodologies also. Another is that parts 1 and 2 focus systematically on discrete-time formulations and solutions of control problems, whereas part 3 describes only continuous-time applications.

The book is probably not suitable for teaching, as standard techniques are only briefly recalled at the beginning of each section, with no special tutorial care, and then rapidly extended or generalized to cope with less standard, additional requirements. As a result, the reader may sometimes feel overwhelmed by tricky notations and long technical developments.

On the whole, the book can be considered a reference for experienced control engineers or researchers interested in the latest developments and improvements in practical control design methods, benefiting from the author’s impressive experience in industrially oriented projects.

**Books Available for Review**

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