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Book review:

CURRENT TRENDS IN NONLINEAR SYSTEMS AND CONTROL

by

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This book, published in the Birkhäuser series *Systems and Control, Foundations and Applications*, contains a collection of papers presented during a two-day workshop, entitled *Applications of Advanced Control Theory to Robotics and Automation* that took place in June 2004 in Rome, Italy. The workshop was organized to honor the 70-th birthdays of two prominent control scientists, P. Kokotovic and T. Nicosia. The contributions included in this book present high quality results, whose authors were either directly or (more often) indirectly inspired by scientific achievements of the honorees. Among 79 contributors, dominated by the Italians, there are both the authors of established renown as well as young doctors. The content of the book is relevant to its title; indeed, it portrays recent developments in control theory from the perspective of their applications in automation and robotics. The spectrum of problems and approaches tackled in the book spans a wide range, from the anti-windup designs, through the collective behavior control of robots, up to the emerging domain of the networked control systems. In most cases, the book consists of survey papers that provide guidelines for a further study of the source literature, but it also contains papers bringing forward novel results.

Taking into account its theoretic, simulation and experimental dimensions, as well as high editorial standards, this book may be recommended as a reference text on modern aspects of control theory to researchers and engineers working in the field of automation and robotics.

The book has been divided into six parts devoted to the following topics: *State estimation and identification* (Part I), *Control and system theory* (Part II), *Robotics* (Part III), *Control of electromechanical systems* (Part IV), *Manufacturing systems* (Part V), and *Networked control systems* (Part VI). Each part of the book splits into chapters. Part I is devoted to observer design for nonlinear systems and linear, time delay systems, and to the identification and state estimation of linear, nonlinear and hybrid systems. The opening chapter in this part, entitled *Circle-Criterion Observers and Their Feedback Applications: An Overview*, by M. Arcak, presents a new approach to the observer design for nonlinear systems consisting in using nonlinearities instead of conquering them.

The observer error dynamics consists of a feedback interconnection of a sector nonlinearity with some linear dynamics. The error convergence can be established on the basis of the circle criterion. The circle-criterion approach has been rooted in some joint publications of the author with P. Kokotovic. The next chapter, *Unknown Input Observers and Residual Generators for Linear Time Delay Systems*, by G. Comte and A.M. Perdon, deals with the problem of designing observers capable of estimating the system state without the knowledge of the control input, and with the problem of constructing the so-called residual generator, i.e. a system, whose output is influenced only by the failure signal from a certain input from the original system. Both problems have been addressed for linear systems with delay, exploiting a representation of the delay system by means of a system over a ring of polynomials in the delay, and generalizing the technique of controlled invariant subspaces in the style of Basile and Marro. Chapter 3, *Set Membership Identification: The $H\infty$ Case*, written by M. Milanese and M. Taragna, addresses fundamental questions of the existence, convergence, robustness, error evaluation, optimality and computational complexity of set membership type (not statistical) identification algorithms for linear, discrete time systems. The chapter *Algebraic Methods for Nonlinear Systems: Parameter Identification and State Estimation*, authored by J. Chiassos, K. Wang, M. Li, M. Bodson and L.M. Tolbert, refers to algebraic methods of parameter identification for system, whose dynamics either cannot be represented as a linear function of unknown parameters or yields an overparameterized representation. A detailed study of identification of two parameters in the model of the induction motor is accomplished using the least squares technique and reducing the problem to solving a certain number of polynomial equations. The last chapter of Part I, *Recent Techniques for the Identification of Piecewise and Hybrid Systems*, by A.Lj. Juloski, S. Paoletti and J. Roll, contains a comparison of the recently developed identification techniques: Bayesian, bounded-error, clustering-based and mixed-integer programming of piecewise affine hybrid systems. An experimental test of these techniques has been accomplished using as a testbed the placement process in a pick and place machine.

Part II of the book, devoted to the analysis and control of dynamic systems, begins with a chapter *Dual Matrix Inequalities in Stability and Performance Analysis of Linear Differential/Difference Inclusions*, written by R. Goebel, T. Hu and A.R. Teel. This chapter constitutes an introduction into performance analysis of the inclusions mentioned in the title. The main message of the chapter consists in studying stability and passivity of a given inclusion along with stability and passivity of its dual inclusion. To achieve this objective, the max function of a family of quadratic functions and a dual convex hull function have been introduced as Lyapunov or storage functions. The next chapter, with the title *Oscillators as Systems and Synchrony as a Design Principle*, presents an exposition of recent results on the behavior of a system of oscillators obtained by R. Sepulchre. A leitmotif of that chapter is the phenomenon of synchrony. Dissipativity theory has been advocated as a tool for the examination of stability and synchrony of interconnected oscillators. Two following chapters, *Nonlinear Anti-windup for Exponentially Unstable Linear Plants*, by S. Galeani, A.R. Teel and Luca Zaccarian, and *Constrained Pole Assignment Control*, written by M. Huba, address the problem of controlling the plants with saturated inputs. The former chapter describes a design procedure of an anti-windup compensator for linear systems. The objective of the windup compensation consists in modifying the design of an unconstrained controller in such a way that prevent a performance deterioration resulting from saturation of the plant input. The latter chapter provides a generalization, to constrained plants, of the linear pole assignment method. It is quite surprising that these two chapters have no overlapping, even in the references quoted. The finite-time control is the subject of the last two chapters of Part II, namely *An Overview of Finite-Time Stability*, by P. Dorato, and *Finite-Time Control of Linear Systems: A Survey*, whose authors are F. Amato, M. Ariola, M. Carbone and C. Cosentino. The chapter written by P. Dorato offers a concise exposition of basic concepts and results concerned with finite-time stability for linear, nonlinear and stochastic systems. The other chapter provides conditions for finite-time stabilization of linear systems, either continuous or discrete, by state or output feedback. The conditions have been formulated as certain LMIs.

Part III of the book, concerned with robotics, includes 8 chapters partitioned equally between the subjects of stationary and mobile robots. In the chapter *An Application of Iterative Identification and Control in the Robotics Field*, by P. Albertos, A. Valera, J.A. Romero and A. Esparza, the model of a single flexible joint of a robot has been used as an illustration of the iterative procedure of intertwined controller design and model identification. The next two chapters deal with classical robotics matters. The chapter titled *Friction Identification and Model-Based Digital Control of Direct-Drive Manipulator*, written by B. Bona, M. Indri and N. Smaldone, makes a comparison of two identification schemes of the rigid manipulator dynamics with friction. The chapter *A Singular Perturbation Approach to Control of Flexible Arms in Compliant Motion*, by B. Siciliano and L. Villani, develops a compliant motion controller for a flexible joint manipulator. A novel result in the area of fault tolerant control of robotic manipulators is included in the chapter *Fault Tolerant Tracking of a Robot Manipulator: An Internal Model Based Approach*, by C. Bonivento, L. Gentili and A. Paoli. The result consists in augmenting the standard tracking control algorithm with an adaptive internal model unit, that yields a fault tolerant controller able to compensate unknown spurious torque harmonics. The chapters devoted to mobile robots begin with the text entitled *Set Membership Localization and Map Building for Mobile Robots*, written by N. Ceccarelli, M. Di Marco, A. Garulli, A. Giannitrapani and A. Vicino, presenting a review of the set-theoretic approach to the localization and map building problem for mobile robots, as an alternative to statistical methods. The following chapter, *Visual Servoing with Central Catadioptric Camera*, by G.L. Mariottini, E. Alunno, J. Piazzi and D. Prattichizzo, sets forth a new visual servoing strategy for holonomic mobile robots equipped with a panoramic camera, relying on the epipolar geometry. The chapter *Motion Control and Coordination in Mechanical and Robotic Systems*, authored by I.V. Miroshnik, develops a collection of conceptual tools for the study of coordinated motion in mechanical systems, including both stationary manipulators and mobile robots. Part III is concluded with a chapter by R. Fierro and P. Song, titled *Coordination of Robot Teams: A Decentralized Approach*. Its main contribution consists in providing a team formation algorithm of nonholonomic mobile robots, based on dynamic linearization, and a framework for decentralized coordination of teams of cooperating robots.

A common denominator of Part IV of the book are applications of modern control techniques to electromechanical systems. That part starts with a chapter *Transient Stabilization of Multimachine Power Systems*, by M. Galaz, R. Ortega, A. Astolfi, Y. Sun and T. Shen. The chapter presents a novel application of the interconnection and damping assignment, passivity-based control methodology to the feedback stabilization of large-scale power systems with lossy transmission networks. The control objective is focused on achieving stability with controlled size of the basin of attraction, that is of particular significance in the fault recovery situation of the power system. An existence result is obtained for general systems, while a constructive solution has been provided for the two machine case. To the same area of large scale systems control refers the chapter *Robust Controllers for Large-Scale Interconnected Systems: Applications to Web Processing Machines*, written by P.R. Pagilla and N.B. Siraskar, dealing with large-scale systems built of linear subsystems, with linear or nonlinear interconnections. A decentralized, adaptive stabilization algorithm has been designed, and dedicated to web processing systems, i.e. manufacturing systems that process materials having the form of continuous, flexible strips, like paper, plastics, textiles, etc. The next chapter, *Control Strategy Using Vision for the Stabilization of an Experimental PVTOL Aircraft Setup*, with authors I. Fantoni, A. Palomino, P. Castillo, R. Lozano and C. Pégard, presents a derivation and an experimental validation of a control law stabilizing position and orientation of a planar vertical takeoff and landing aircraft. The last chapter in Part IV, *Neural Network Model Reference Adaptive Control of Marine Vehicles*, by A. Leonessa, T. VanZwieten and Y. Morel, provides a general framework for modeling and controller design for marine vehicles, with a special emphasis on neural network controllers.

Part V of the book includes three chapters, of which the first, *Projection and Aggregation in Maxplus Algebra*, by G. Cohen, S. Gaubert and J.-P. Quadrat, develops a module theory justification of the existence conditions for linear projectors in maxplus algebra. The topic of the respective research has been rooted in a paper on aggregation and coherency in Markov chains, co-authored by P. Kokotovic, and is motivated by the aggregation problem in dynamic programming. The remaining chapters in Part V treat manufacturing systems in a more direct way. The chapter *A Switched Model for the Optimal Control of Two Symmetric Competing Queues with Finite Capacity*, by M. Boccadoro and

P. Valigi, concerns optimization of the transient behavior of a two-part type, make-to-order manufacturing system. Chapter 3, with the title *Cooperative Inventory Control*, whose authors are D. Bauso, R. Pesenti and L. Giarré, presents a novel hybrid model of the multi-retailer inventory system, and a design of a neuro-dynamic programming control algorithm for the system.

Part VI of the book deals with the analysis and design of networked control systems. The chapter *Communication Logic Design and Analysis for Networked Control Systems*, written by Y. Xu and J.P. Hespanha, deals with distributed control of a system of linear processes communicating through a network. Stochastic and deterministic communication logics are considered, and conditions proved for boundedness of the estimation errors and the trade-off between the amount of exchanged information and the system performance. The next chapter, authored by R. Ciferri, G. Ippoliti and S. Longhi, and titled *Networked Decentralized Control of Multirate Sampled-Data Systems* examines the stabilization problem in decentralized control of a large-scale, linear plant, whose input-output channels admit different sampling and updating intervals. Its main result consists in providing existence conditions for a solution of the networked decentralized multirate control problem. The book is closed by the chapter *Finite-Time Stability for Nonlinear Networked Control Systems*, written by S. Mastellone, P. Dorato and Ch.T. Abdallah. Nonlinear, affine control, discrete-time models of both the plant and the state estimator are assumed, with a network transmitting signals from the plant sensors. A new concept of extended finite-time stability (if the system trajectory crosses a bound, then it comes back to within the bound after a given number of steps) is introduced, and sufficient conditions of extended finite-time stability for networked control system are proved.

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