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Book review for "Stability and Control of Dynamical Systems with Applications: A tribute to Anthony M. Michel"

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D. Liu and P. J. Antsaklis, editors. *Stability and Control of Dynamical Systems with Applications: A tribute to Anthony M. Michel*. Control Engineering. Birkhäuser, Boston, 2003.

This book is the outcome of a one-day workshop in Honor of Anthony N. Michel that took place on April 5, 2003 at the University of Notre Dame. The preface summarizes Prof. Michel's long and productive career as a researcher, teacher, and administrator. The remaining 21 chapters consist of research papers authored by colleges, collaborators, and former students. Prof. Michel's contributions to the research community transpire throughout the whole book.

The range of topics covered is wide: the first seven chapters address topics in systems' theory, mostly related to stability; the next six chapters address problems in estimation, signal processing, and optimization; and the final eight chapters describe applications of dynamical systems, ranging from power systems to cellular networks.

The main virtue of the book is to provide a broad view of topics, techniques, and applications of systems' theory. Probably reflecting Prof. Michel's interests, the stability of dynamical systems is the topic covered more thoroughly (Chapters 2–7, 18). This topic is addressed in the context of mechanical systems, hybrid systems, swarms of mobile agents, congestion control, switched systems, and algebraic systems. State estimation and system identification is also addressed in several chapters (8, 9, 11, 13, 17, 20). Chapters 8 and 13 address fairly general system identification problems, whereas chapters 9, 11, 17, and 20 are focused on specific applications, which include blind source recovery, aircraft dynamics, groundwater systems, and reliability in offshore oil and gas platforms. Chapters 10, 12, and 19 explore the use of numerical techniques to solve optimization problems. One of these proposes an evolutionary algorithm to find the Pareto-optimal solutions to a multi-criteria optimization problem. The other two chapters are devoted to the solution of optimal control problems and present numerical methods based on dynamic programming. Chapters 14–16 provide an overview of problems in the area of power systems. From these, 14 and 16 have significant tutorial values and introduce the reader to techniques, challenges, and open problems in this area. Chapter 15, addresses the timely problem of emergency control in large electrical power systems. Chapter 21 presents an additional application of control to the problem of call admission in cellular networks. The remaining of this review provides a brief summary of the different chapters.

Part I: Issues in Stability Analysis

▷ A. Fettweis, "Chapter 1: Wave-digital concepts and relativity theory"

This chapter explores an analogy between the equations of a nonlinear inductance and the equations of motion of a particle given by the relativity theory. This analogy motivates an alternative formulation of relativistic dynamics, which is consistent with classical relativity for problems concerning collisions of particles or the action of fields over moving particles. However, in this new formulation both Newton's second and third laws need to be altered, as opposed to classical relativity in which the second law is changed but the third law remains untouched.

▷ L. Gruyitch, "Chapter 2: Time, systems, and control qualitative properties and methods"

This chapter, develops an abstract notion of time and physical systems. For linear systems, it introduces the notion of a "complete transfer function" that captures both the forced and the homogeneous response of a system. For nonlinear systems it introduces a characterization of Lyapunov stability in terms of a family of functionals and vector Lyapunov functions.

▷ J. Shen *et al.*, "Chapter 3: Asymptotic stability of multibody attitude systems"

This chapter addresses the dynamics of a rigid body with multiple elastic subsystems, which is supported by a fixed pivot point but is free to rotate in three dimensions. The asymptotic stability of the system is investigated, based on a suitably constructed mathematical model for the system dynamics.

▷ H. Lin *et al.*, "Chapter 4: Robust regulation of polytopic uncertain linear hybrid systems with networked control systems applications"

This chapter addresses the design of a feedback controller for a hybrid system that guarantees a pre-specified closed-loop behavior, in spite of uncertainty in the process dynamics. The design method proposed is based on reachability computations. The method is shown to be applicable to the design of digital controllers for certain classes of networked control systems.

▷ K. Passino, 'Chapter 5: 'Stability analysis of swarms in noisy environments"

This chapter addresses the dynamics of "swarms" of point-agents interacting through simple attraction/repulsion laws. Lyapunov-based methods are used to investigate the stability of the swarm behavior and the effect of measurement noise in the agents' dynamics.

▷ Sichitiu *et al.*, "Chapter 6: Stability of discrete time-varying linear delay systems and applications to network control"

This chapter addresses the stability of discrete-time switched systems with constraints on the allowable sequence of switches. A necessary and sufficient condition for asymptotic stability is provided. This result is used to investigate the stability of ATM congestion control mechanisms

▷ G. Zhai, "Chapter 7: Stability and $\mathcal{L}_2$ gain analysis of switched symmetric systems"

This chapter addresses the stability of switched symmetric systems. These are systems that result from switching among LTI systems with symmetric Rosenbrock matrices. It is shown that switching among such systems cannot destroy asymptotic stability neither increase their input/output $\mathcal{L}_2$ induced-norm. Delayed switched systems are also considered.

Part II: Neural Networks and Signal Processing

▷ I. Sandberg, "Chapter 8: Approximation of input-output maps using Gaussian radial basis functions"

This chapter addresses the approximation of operators between function spaces using Gaussian radial basis functions (GRBF). It is shown that certain classes of shift-invariant input-output systems can be uniformly approximated over an infinite time/space domain using GRBFs defined in a finite-dimensional space. This result finds application, e.g., in system identification and adaptive control.

▷ K. Waheed *et al*, "Chapter 9: Blind source recovery: a state-space formulation"

This chapter addresses blind source recovery, i.e., the estimation of input signals to a filtering environment by observing only the outputs from this environment. The authors formulate the problem in the state-space, which permits them to consider nonlinear and time-varying environments.

▷ L. Yang *et al*, "Chapter 10: Direct neural dynamic programming"

This chapter surveys several techniques for approximate dynamic programming, which include reinforcement learning, adaptive critics, neural-dynamic programming and adaptive dynamic programming. It then proceeds to use direct neural-dynamic programming to control an Apache helicopter. A detailed nonlinear model of the helicopter is used for a simulation study.

▷ J. Farrell *et al*, "Chapter 11: Online approximation-based aircraft state estimation"

This chapter addresses the state and parameter estimation for aircraft nonlinear models. Convergence is established using Lyapunov-based arguments.

▷ G. Yen, "Chapter 12: Evolutionary multiobjective optimization: qualitative analysis and design implementation"

This chapter addresses the computation of Pareto-optimal solutions to a multi-objective optimization problem using evolutionary algorithms. The proposed algorithms explore the whole Pareto front by keeping the diversity of the individuals along the trade-off surface. The algorithm is compared with alternative approaches in a benchmark problem.

▷ Y.-F. Huang, "Chapter 13: Set-membership adaptive filtering"

This chapter addresses system identification in a set-membership framework, where parameters are said to be *feasible* is they are able to explain the measured data for given worst-case bound on the (deterministic) measurement error. The chapter discusses the main features of this approach to system identification.

Part III: Power Systems and Control Systems

▷ M. Pai *et al*, "Chapter 14: Trajectory sensitivity theory in nonlinear dynamical systems: some power system applications"

This chapter addresses the sensitivity of solutions to nonlinear Differential Algebraic Equations (DAE) with respect to parameter variations, a problem often known as Trajectory Sensitivity Analysis (TSA). The paper describes several applications of TSA in the area of power systems.

▷ V. Vittal, "Chapter 15: Emergency control and special protection systems in large electrical power systems"

This chapter addresses the mitigation of large disturbances in electrical power systems, such as the loss of several generating units or transmission lines. The approach proposed starts by separating the network into smaller islands, followed by load-shedding based on the rate of frequency decline. The islands are formed automatically based on a two-time-scale procedure that attempts to minimize the generation-load imbalance within each island.

▷ A. Bose, "Chapter 16: Power systems stability: new opportunities for control"

This chapter discusses several key control systems that are present in power systems. The discussion highlights current challenges and opportunities for the control research community.

▷ D. Porter, "Chapter 17: Data fusion modeling for groundwater systems using generalized Kalman filtering"

This chapter addresses the estimation of groundwater dynamics for waste management, water supply, and geotechnical applications. It proposes a computationally tractable technique to fuse measured data, physical laws, and statistical models for spatio-temporal dynamics. The technique is applied to data from the DOE Savannah river site, where a hazardous waste burial location can be found.

▷ M. Sain *et al*, "Chapter 18: (Control,Output) synthesis: algebraic paradigms"

This chapter addresses the characterization of the possible closed-loop transfer matrices by solving two problems:

1. The Nominal Design Problem (NDP) consists of finding "good" transfer matrices $M(s)$, $T(s)$ such that $P(s)M(s) = T(s)$, for a given plant transfer matrix $P(s)$. The transfer function $M(s)$ can be viewed as an open-loop controller and $T(s)$ as a desired plant response. "Good" refers to properties such as stability.
2. The Feedback Synthesis Problem (FSP) consists of finding a closed-loop controller transfer matrix $C(s)$ such that the "closed-loop" transfer matrix $(I - C(s)P(s))^{-1}C(s)$ equals a given transfer-matrix $M(s)$.

The two problems are solved in a coordinate-free way.

▷ J. Murray *et al*, "Chapter 19: The adaptive dynamic programming theorem"

This chapter proposes a procedure to iteratively solve the Hamilton-Jacobi-Bellman equation based on numerical simulations of the system dynamics. The procedure is proved to converge to the optimal value function.

▹ K. Erickson *et al*, “Chapter 20: Reliability of SCADA systems in offshore oil and gas platforms”

This chapter addresses the estimation of the mean time between failures (MTBF), system availability, and probability of facilities damage/pollution release in offshore oil and gas platforms.

▹ D. Liu *et al*, “Chapter 21: Power control and call admission control for DS-CDMA cellular networks”

The chapter addresses the admission control problem in Direct-Sequence Code-Division Multiple-Access (DS-CDMA) cellular networks. The decision to reject a call request is based on the existence of acceptable power control setpoints for the new call and all existing ones.