BOOK REVIEWS

Systems and Control in the Twenty-First Century

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This volume includes 23 articles of those presented as plenary addresses, invited addresses and minisymposia at the *12th International Symposium on the Mathematical Theory of Networks and Systems*, held in St. Louis, Missouri, USA, June 24- 28, 1996. They were written by leading researchers, on the vanguard of the development of systems, control and estimation for the next century. They were concerned with the application of new methodologies to distributed parameter systems, linear/ nonlinear systems and stochastic systems for solving problems in areas such as aircraft design, circuit simulation, imaging, speech synthesis and visionics.

D. Alpay and I. Gohberg present in their contribution *State Space Method for Inverse Spectral Problems* some explicit formulas for the potential of the differential operator, or the local reflexivity coefficient function, when the spectral matrix function (or equivalently the scattering matrix function or the reflection coefficients function) is rational, and gives applications of these formulas to the equivalence between Krein's and Marchenko's approaches to inverse problems in the rational case. In general, the results presented are yielded by a method which is based on the state space method in the system theory.

The second paper, *New Developments in the Theory of Positive Systems*, by B.D.O. Anderson, deals with some special finite- dimensional linear systems problems, broadly speaking the ones where the matrices underlying the state-variable descriptions of the systems considered contain nonnegative or positive entries. The paper focuses on three problems: the so-called positive linear system realization problem, the problem of exponential forgetting of initial conditions and an associated smoothing issue in hidden Markov models, given the collection of probabilities for outputs strings. The paper begins with two motivational sections based on some examples of positive systems and some general questions about the systems, and proceeds on reviewing the Perron-Frobenius theory on the eigenstructure of nonnegative matrices, and making a generalization of this theory, and concludes with a list of open problems.

In their contribution on *Modeling Methodology for Elastomer Dynamics*, H.T. Banks and Nancy Lybeck discuss a dynamic partial differential equation (PDE) formulation based on large deformation theory elasticity as an alternative approach to the strain energy function (SEF) formulation. For illustrative purposes, models using PDE formulation for both simple extension and generalized simple shear, are presented.

D. Boley's and B.N. Datta's paper *Numerical Methods for Linear Control Systems*, is concerned with three aspects: first, to point out the difficulties in computational setting associated with many important theoretical methods; second, to outline some of the best ones from a numerical viewpoint; and third, to show the sensitivity degree of some of the problems addressed in the literature. This is done only for quite a few selected problems and especially for continuous-time methods. Some material of the paper was inspired by the book: *Numerical Methods for Linear Control Systems Design and Analysis*, and completed by B.N. Datta . For the last twenty years or so, numerically effective techniques have been developed for most of the linear algebra problems (controllability and observability problems, the prob-

lem of computing an exponential matrix e^{AT}, the matrix equations problems: Lyapunov equations, Sylvester equations, the algebraic Riccati equations, the pole-placement problems, stability problems, and frequency response problems).

Roger Brockett's paper comments on stochastic processes on manifolds . After presenting probability distribution on the circle and some mathematical preliminaries, the paper goes on with Riemannian manifolds, diffusion processes, processes defined on submanifolds, degenerate diffusions and finally gradient systems and skew terms. The paper actually makes a contribution to the literature on computer vision, with an explosive growing in the last years.

C.I. Byrnes' and A. Lindquist's paper *On Duality between Filtering and Interpolation* is a survey on the rational covariance extension problem, a problem with historical roots at the beginning of the century. Section 2 formulates the rational covariance extension problem. Section 3 discusses the partial stochastic realization problem, and modeling filters and applications. Section 4 presents a fast Kalman filtering algorithm as a device for spectral factorization and as a preamble to Section 5, where an observation that filtering and interpolation induce dual, or complementary, decompositions of the space of positive real rational functions of a degree less than or equal to n, is formalized. Based on this formalization, Section 6 provides a full parameterisation of all positive rational extensions of a given partial covariance sequence, and makes a new proof that the problem is well-posed. Section 7 is an alternative full parameterization of all rational extensions in terms of unique positive semidefinite solutions of a non-standard Riccati-type matrix equation, and Section 8, the final section,includes a series of simulations.

M. Fliess, J. Levine, P.Martin, F.Ollivier and P.Rouchon dedicate their paper *Controlling Nonlinear Systems by Flatness* to the following main topics: systems and diffities, equivalence and flatness, differential flatness and dynamic feedback linearization, nonholonomic mechanical systems and an application of a general one-trailer system.

In *How Set-Valued Maps Pop Up in Control Theory*, H. Frankowska presents four instances where set-valued maps intervene either as a tool to state the results or as a technical proof tool. The paper includes four distinct Sections: set-valued optimal synthesis and differential inclusions, viability kernel, nonsmooth solutions to Hamilton-Jacobi-Bellman equations and interior and boundary of reachable sets.

In his paper *Circuit Simulation Techniques Based on Lanczos-Type Algorithms*, R.W Freund describes the computation of Padé-based reduced-order models of large linear network via Lanczos-type algorithms. The paper focuses on Padé's approximations of transfer functions, the single-input single-output case, a Lanczos-type algorithm for multiple starting vectors, a connection to matrix Padé's approximation and some related work.

The next paper, *Dynamical Systems Approach to Target Motion Perception and Ocular Motion Control* by B.K. Ghosh, E.P. Loucks, C.F. Martin and L. Schovanec, is a dynamical systems approach to two problems. The first problem is to dynamically estimate the motion parameters of a moving target and the second problem is to dynamically control the orientation of the visual system. The problem of orientation control of a visual system for tracking a given moving target is an example of perspective control, a notion which this paper introduced.

The interaction between numerical linear algebra and control theory crucially marked the development of numerical algorithms for linear systems in the past. U. Helmke's and K. Hüper's paper *The Jacobi Method: A Tool for Computation and Control* considers a generalization of the classical Jacobi method for symmetric matrix diagonalization, that applies to a wide range of computational problems. In recent years Jacobi-type methods have attracted large interest, due to their high accuracy properties and inherent parallelism as compared to QR-based methods. Being a survey paper, no complete proofs of the reported results are met.

The paper *Ellipsoidal Calculus for Estimation and Feedback Control*, by A.B. Kurzhanski, emphasizes the constructive techniques for modeling and analysis of an array of problems of guaranteed control synthesis and set-valued estimation for systems that operate under "set-membership uncertainty" - unknown but bounded inputs and disturbances, and presents a unified approach to those topics, based on descriptions making use of notions in set-valued calculus.

The paper *Control and Stabilization of Interactive Structures* by I. Lasiecka includes three sections. The first section provides an overview of various results in LQR and Riccati theory for abstract systems with unbounded controls. Two cases of parabolic and hyperbolic like dynamics are distinguished. This Section also briefly discusses general results in the controllability and stabilizability of such dynamics. Particular emphasis is placed on such a question as to what is/ what is not possible to achieve with a given type of actuators. Section 2 presents the sta-

bility theory relevant to nonlinear thermoelastic plates. Section 3 deals with the boundary control problems and related Riccati equations meant for several models of linear thermoelastic plates.

The problem of *Risk Sensitive Markov Decision Processes* is discussed in the paper with this title authored by S.I. Marcus, E. Fernández- Gaucherand, D. Hernández-Hernández, S. Coraluppi and P. Fard. The discussion is orientated on the following topics: the risk sensitive MDP (Markov Decision Processes) model, complete state observations, partial state observations, alternative risk sensitive approach. The paper summarizes some contributions to achieving results that parallel those already available in a risk-neutral setting, as well as to identifying connections of risk-sensitive control to robust control and differential games.

The paper *On Inverse Spectral Problems and Pole-Zero Assignment*, by Y.M. Ram, presents the pole and zero assignment problem for simply connected systems by passive control, and an explicit solution of the partial pole assignment problem for the system concerned. The problem of assigning both poles and zeros for un undamped system is finally addressed. How to simultaneously assign certain poles and zeros by appropriately selecting the position vector and the control function, is also shown.

Inverse Eigenvalue Problems for Multivariable Linear Systems, by J. Rosenthal and X.A. Wang, resumes some of the material presented at a minicourse of MTNS and surveys advances in the area of inverse eigenvalue problems. These advances are mainly based on several strong theorems of algebraic geometry. In order to explain this connection and make the article self contained, the most important concepts in algebraic geometry are summarized in the paper. Other problems paid attention to in the book are the static pole placement, the dynamic pole placement and general matrix extension.

The paper *Recursive Designs and Feedback Passivation*, by Rodolphe Sepulchre, Mrdjan Janković and Petar V. Kokotović, reformulates the problem of feedback stabilization as feedback *passivation* so that the construction of a stabilizing feedback should be translated into the construction of a passivating output. This constructing is restricted by two geometrical requirements of passivity: a relative degree one and a minimum phase property. How backstepping and forwarding, the two building blocks of recursive Lyapunov designs, complement each other by in turn removing one of the two obstacles by feedback passivation, is also shown.

In the paper *Ergodic Algorithms on Special Euclidean Groups for ATR* (Automated Target Reconstruction), A. Srivastava, M.I. Miller and U. Grenander describe a technique for estimating motions of rigid targets based on deformable template representations of complex scenes. The paper explains the parameterization of signal motion using group actions, and the SE(n) geometry leading to tools for constructing stochasting flows. A Bayesian formulation of the problem, together with an algorithm for solving the motion estimation problem in this Bayesian context, is provided. The implementation results for various specific scenarios are also presented.

H.J. Sussmann, in his paper titled *Some Recent Results on the Maximum Principle of Optimal Control Theory*, announces a new result that contains, generalizes and combines most of the existing versions. This new version applies to "hybrid systems", i.e. systems made up of pieces of different kinds, each one of which falls under the scope of one of the existing versions. In addition, this version applies to problems where none of the other versions can be used, and gives better results even in some cases where one of the older versions is applicable. The following are discussed in the paper: multidifferentials of set-valued maps, a separation theorem, multidifferential of flows, point variations of a flow, the maximum principle and some applications.

The paper, *Nonlinear Input-output Stability and Stabilization*, by A.R. Teel, is an illustration of how nonlinear stability analysis and control synthesis has recently used the input-output method . The focus is on the results in the L_∞ setting. The point is to give a flavour of what results there are reflected in the literature, but many other results not being discussed and many interesting open problems still remaining, most notably those associated with general gain assignment and related computational issues.

The paper *Repetitive Control Systems: Old and New Ideas*, by G. Weiss, is dedicated to a natural control problem for trying to track a periodic signal with the output of a plant, or to reject a periodic disturbance acting on a control system. This problem is treated in Sections 1 and 3 of the paper: Section 2 lays the background. Section 4 shows a way of generating these ideas to cope with superpositions of periodic signals of arbitrary periods.

The paper *Fitting Data Sequences to Linear Systems*, by Jan C. Willems, reviews some basic notions and results from the behavioral approach to dynamical systems. Equivalent Kernel representations, and the notion of more pow-

erful models in the context of a Kernel description model class, as well as the recursive computation of the MPUM (Most Powerful Unfalsified Model) are presented. The theory of *infinite* vector time-series is extended to the modeling of *finite* vector time-series . System theory language is used to prove the importance of the Berlekamp-Massey algorithm for decoding Reed-Salomon codes.

The last paper of the volume, *Fighter Aircraft Control Challenges and Technology Transition*, by K.A. Wise, includes topics in integrated controls, reconfigurable flight control, aircraft performance improvements, and aircraft/missile robust nonlinear control, hopefully viewed to stimulate academic research in these areas, and to promote technology transfer from academia to industry.

The book is addressed to students and professionals not only in electrical engineering, but also in mechanical, chemical engineering, and mathematics. This is not a book for the uninitiated: some mathematical maturity is essential.

To conclude with, this is a unique book in terms of topics selected and the approaches made. This reviewer believes that it is a very useful book for the on-going researches in the field of control systems theory and for the application of new methodologies.

Theodor Dan Popescu