BOOK REVIEWS

Computation and Control IV

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Considerable effort has been invested in recent years in developing rigorous numerical methods and computational tools for control systems analysis and design. Computational problems in control theory are complex ones. Fortunately, these problems often present special structures which, if exploited, can produce both theoretical and computational results. Moreover, problems that arise from applications are best addressed by interdisciplinary teams, where experts in various disciplines work together and create numerical algorithms for control design. Such communication often produces new research problems in specific disciplines. The Fourth Bozeman Conference brought together leading experts in control theory, numerical mathematics and various application areas, to discuss recent developments in interdisciplinary approaches to computational control.

The reviewed volume includes 23 contributions (39 authors, mainly from the United States of America), presented at the above mentioned conference. Most contributions are written in a mathematical formal style, stating new theorems and proving results. The theoretical treatment is often accompanied by illustrative numerical and graphical results.

A wide spectrum of topics is covered. A number of papers address some modeling and estimation problems. A paper presents well-posedness results for a class of one-dimensional nonlinear beam models with linear damping and general external time dependent forcing in the Sobolev space H^{-2}. The proof technique combines constructive functional analytic arguments used for linear systems with monotonicity arguments used for nonlinear equations.

Another paper deals with modelling and parameter estimation for an imperfectly clamped (thin circular) plate, an important problem for structural and acoustic systems encountered in flight devices (fuselages, helicopter blades). The modelled boundary conditions involve four parameters experimentally fitted, to consider some

variance (due to oscillations) in both the displacement and slope.

A paper refers to a problem in aircraft engine testing, and illustrates the numerical difficulties (singularities, poor scalings, local minima) arising when a simplified version of a "forebody simulator" is used.

An integral representation of the LQR feedback operators for hyperbolic systems (one-dimensional wave equation with Kelvin-Voight damping), is investigated in another article. This is useful for designing suboptimal low order dynamic compensators and for optimal sensor location.

Several authors have studied the steady state response to Burgers' equations—quasi-linear parabolic partial differential equations—with varying viscosity, which model diverse physical phenomena, such as turbulence, shock flows, traffic flows, acoustic transmission in fogs. Under very special conditions, exact and complete solutions can be found in terms of the initial values. Both theoretical results and numerical simulation effects are put forward.

Another article deals with the accuracy of discrete observations of the heat equation on a bounded domain. The error in estimates is shown to depend on the tail of the Fourier expansion of the initial condition; the size of the tail sometimes depends on the smoothness of the initial condition.

A comparison of two estimation methods (minimum mean-squared error and regularized least squares) for hydraulic conductivity functions, is dedicated a paper included in the volume. The research is motivated by the need of improved, physically based models of transport processes in heterogeneous media, with application to environmental impact of contaminated groundwater.

In some applications, such as seismic and ultrasound modelling and imaging, material parameters may have rapid variations; these variations are often modelled by hyperbolic partial differential equations with discontinuous parameters. As asymptotic techniques or finite difference methods meet barriers when applied to discontinuous coefficient equations, an adaptive stencil scheme is considered in another paper; this scheme combines the Courant-Isaacson-Rees method, the essentially non-oscillatory scheme and the Strang splitting. Numerical results are presented.

Another paper presents a Sinc-Galerkin scheme for approximating the eigenvalues of Sturm-Liouville differential equations with mixed boundary conditions. With an appropriate choice of basis functions, the transformed problem retains the symmetry and the elements of the matrices involved are easy to find.

A related topic is the use of Sinc-Galerkin Schwarz alternating method for Poisson's equation on a rectangle, studied in a companion paper.

Other authors analyze a cross validation method for obtaining a stable, data-based, approximate solution to a general class of first kind Fredholm integral equations from finite, discrete, inaccurate data. The method obtains a truncation level in a truncated singular value decomposition, which exhibits the same asymptotic behaviour as that obtained by the most successful to date generalized cross validation technique, i.e. Wahba's.

The volume also includes a paper which solves the one-dimensional heat equation with discontinuous initial condition using the heat kernel and the Sinc collocation method for convolution integrals. Numerical results, and tables of errors for different values of spatial and temporal mesh sizes, are also presented.

Another article describes a strategy for estimating the diffusion and kinetic terms in a reaction-diffusion system, in which each of the chemical species has the same diffusion coefficient, and profiles of each species are available. One such class of phenomena is the catalytic reaction of gases at gas-metal interfaces, which is of large interest due to recent advances in electron microscopy techniques. A model is proposed, and the existence of travelling wave solutions is asserted.

Several papers address some related control problems. Results concerning the numerical solution of a weighted mixed-sensitivity H_∞-control design for irrational transfer matrices

which have decompositions into a rational matrix and an H_∞-part, are presented in one article. A simple model reduction approach is used. The proposed technique has several advantages over previously used techniques: only finite-dimensional Riccati equations need to be solved, no initial factorization step is involved, and the approach coverage is for a wide class of unstable multivariable systems.

Another paper discusses the controller design for infinite-dimensional systems using finite-dimensional linear robust control system design tools (H_∞ and μ-synthesis). An important property of the design method lies in that it requires knowledge of only a small number of eigenvalues and eigenvectors of state space operator; this allows the method to be applied to models with complicated shapes. A wave equation is considered for numerical and graphical illustration.

Another topic discussed is preserving exponential stability under approximation for distributed parameter systems. An important sufficient condition for approximating feedback gains in a linear quadratic regulator problem is that the approximation scheme maintains the stability behaviour of the original system.

One article establishes the existence and smoothness of functional gains for LQR feedback control of parabolic systems. Provided that algebraic Riccati equation has sufficiently smooth solutions, the feedback gain operator has explicit representations, even if the control space is infinite-dimensional. A specific problem, governed by the one-dimensional heat equation with rather general input operators, is considered.

Another paper formulates a mathematical model for the process of human binocular vision, and establishes the conditions under which the position of a moving rigid object can be distinguished; such a model is useful in medical diagnosis.

A related topic is that of dynamics of ocular motions; tracking models for moving objects are developed based on models of monocular and binocular vision, and computer simulations.

An interesting application of linear control theory ideas is the development of a common framework for splines, including polynomial and generalized exponential splines of all orders. This topic is investigated in a paper, which also proposes a spline interpolation methodology for two-dimensional problems. In many applications (such as in air traffic control), what is given is a set of points through which the system must traverse at specified times. Another application is the storage of traced curves, such as signatures, with a minimal number of points.

Another paper establishes exact boundary controllability of an Euler-Bernoulli beam and mass system, and shows that the system may be steered to its equilibrium state in an arbitrarily short time interval by applying a torque to the end of the beam.

A multigrid method for total variation-based image denoising is investigated in a short article. Mathematically, denoising (or noise removal) means the solution of an operator equation $Au = u$; this is a special case of image reconstruction. Standard methods tend to work poorly when u is not smooth. So, a least squares total variation (TV) minimization problem seems to be useful to overcome this difficulty. To solve the TV problem, a fixed point iteration is introduced, containing a differential operator with diffusion coefficient. A cell-centered finite difference discretization and a variant of the multigrid algorithm are used for solving the resulting discrete linear system.

A final paper investigates the use of the Heisenberg and Jacobi groups for signal processing applications. The proposed method combines the sampling techniques of both window Fourier transform and wavelet techniques, and promises to offer the advantages of both.

Many references are included at the end of each paper. By its comprehensive coverage, and due to the included theoretical and computational results, related to the solution of important practical problems, the reviewed book is a definitely valuable guidance for mathematicians, and mathematically oriented scientists and engineers.

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