Control and Estimation of Distributed Parameter Systems

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Recent advances in control and estimation for nonlinear distributed parameter systems are surveyed in 16 original papers, presented at the International Conference on Control of Distributed Parameter Systems, held in Graz, Austria, July 15-21, 2001. This conference was the eighth in a series of conferences starting with 1982. Theoretical and numerical issues are addressed. Investigated topics include: numerical methods for partial differential equations (PDEs); optimal control in fluid mechanics; shape optimisation, etc.

Chapter 1, State Estimation and Tracking Control of Nonlinear Dynamical Systems by H.T. Banks, S.C. Beeler, and H.T. Tran, develops efficient techniques for constructing suboptimal nonlinear estimators and tracking controllers for a large class of systems. The techniques are based on a "state-dependent Riccati equation" (SDRE), related to the standard approach for linear systems. The associated theory is developed, and simulation results for test problems are compared with those obtained using linear control and (partially non)linear estimators. The proposed techniques have significantly improved performance over established control techniques. The limitations are related to the simplifying assumptions made.

Chapter 2, A Well-posedness Result for a Shear Wave Propagation Model by H.T. Banks, H. Tran, and S. Wynne, deals with a nonlinear model of one-dimensional shear waves in a viscoelastic tissue, and proves the existence and uniqueness of solutions. The model arises in inverse problems related to detection and characterization of cardiac artery stenoses. The investigated model has linear internal strain variables but nonlinear stress-strain interactions. Weak solutions are defined, and a Galerkin approximation is used to prove the results for local and global weak solutions.

An abstract parameter identification problem for PDEs with finite number of parameters is investigated by R. Becker and B. Vexler in the paper **Mesh Adaptation for Parameter Identification Problems.** The state equation is discretized by a finite element method on locally automatically refined meshes. A cheap a posteriori error estimator is developed and used to improve the accuracy by suitable mesh refinements. Numerical results on prototype one-dimensional problems illustrate the performance of the technique.

Chapter 4, A SQP-Augmented Lagrangian Method for Optimal Control of Semilinear Elliptic Variational Inequalities by M. Bergounioux and M Haddou, investigates an efficient technique for optimal control problems described by semilinear elliptic variational inequalities with constraints on the control. Lagrange multipliers may not exist, except for relaxed problems, under suitable qualification conditions. The problem is well approximated by an augmented Lagrangian method coupled with a Gauss-Seidel splitting. Convergence results for a "continuous" algorithm are proven, and preliminary numerical results are shown.

In **Chapter 5**, **On the Long Time Behavior of Approximating Dynamical Systems**, J.A. Burns and J.R. Singler analyse the impact of using "time marching" algorithms for computing asymptotic solutions of nonlinear differential equations. They show that stable and consistent approximating schemes on a finite precision machine can produce results which do not correspond to the true asymptotic solutions, hence "numerical proofs" of non-uniqueness may not be valid. This difficulty cannot be avoided by using additional side constraints on the boundary value problem. The theory is illustrated by several examples.

Chapter 6, **Error Estimates in Space and Time for Tracking-type Control of the Instationary Stokes System** by K. Deckelnick and M. Hinze, addresses an optimal tracking problem for Stokes flows in two or three space dimensions. Using the first order optimality conditions, the solution is approximated by finite elements in space and implicitly in time. Optimal error estimates are derived and confirmed by numerical results.

In **Chapter 7, Modeling and Control of Asymptotic Shells,** M.C. Delfour presents new results for an asymptotic model of thin shells involving two equations, a generalized membrane shell equation and a generalized bending equation for the projection of the asymptotic solution onto the space of inextensible deformations. By a suitable choice of the projection, the two equations are decoupled. The theory is applied to a thin shell model for small vibrations.

Chapter 8, Unbounded Observers and Riccati Operators in Nonreflexive Spaces, by W. Desch, E. Fasanga, and J. Milota, investigates an infinite horizon linear quadratic control problem in a Banach space. The control and observation operators are unbounded. The existence of Riccati operator solution (in a feedback form) is proven, under trace regularity, admissibility and finite cost conditions; it is the minimal positive solution of the Riccati equation.

In **Centroidal Voronoi Tessellation Based Proper Orthogonal Decomposition Analysis,** Q. Du and M.D. Gunzburger propose a hybrid method for model reduction, CVOD, combining the ideas of Centroidal Voronoi Tessellation (CVT) and the popular Proper Orthogonal Decomposition (POD). CVT may be viewed as a clustering technique. The governing PDEs are projected using Galerkin method over the subspace spanned by the CVOD basis. Smaller eigenproblems (for clusters) are solved in comparison with POD.

Chapter 10, Time and Norm Optimal Controls for Linear Parabolic Equations: Necessary and Sufficient Conditions, by H.O. Fattorini, proves a sufficient condition for optimality of controls for parabolic PDEs with a pointwise bound on the controls, and investigates its relation with known necessary conditions.

In **Chapter 11**, **Feedback Stabilization for the 2D Oseen Equations: Additional Results**, A.V. Fursikov gives a new construction of a minimal norm extension operator for the initial condition of the stabilized boundary value problem. This construction is also motivated by a unique continuation property for adjoint steady-state Oseen equations using Carleman estimates.

Chapter 12, **Pontryagin's Maximum Principle via Singular Perturbations,** by G. Grammel, proves necessary optimality conditions for the time optimal control under pointwise state constraints, for a parabolic equation coupled with an ODE in a Banach space. Such systems appear in modelling population dynamics in a contaminated environment. Ekeland's variational principle in combination with a singular perturbation technique is used for regularization. Dirac impulses on boundary are avoided.

Chapter 13, Level Set Methods for Variational Problems and Applications, by K. Ito, formulates several problems (inverse interface, shape optimization, etc.) as a variational problem with respect to a class of admissible interfaces, represented by the zero level set of a level set function. A performance index is minimized over a class of unknown interfaces, or admissible boundary shapes. Preconditioning techniques and a Gauss-Newton method are discussed, and applied to a numerical example for an obstacle problem.

In **Chapter 14**, **Boundary Observability of Compactly Perturbed Systems**, by V. Komornik and P. Loreti, a constructive approach, based on compactness-uniqueness arguments, is used for studying the observability of compactly perturbed linear PDEs.

Chapter 15, Some Shape Optimal Control Computations for Navier-Stokes Flows, by S. Manservisi, analyses an incompressible, viscous flow in a two-dimensional square for minimizing the tracking velocity functional by adjusting the shape of part of the boundary. The shape gradient of the design functional is derived using the adjoint, and Lagrange multipliers methods. Numerical examples are given, using isoparametric finite elements and a projected gradient algorithm.

Finally, **Chapter 16, Model Development for the Positioning Mechanisms in an Atomic Force Microscope**, by R.C. Smith and M.V. Salapaka, develops distributed models for the piezoceramic positioning mechanisms used in atomic force microscope design. Hysteresis and constitutive nonlinearities are considered. Numerical approximate techniques are summarized and the accuracy of the results for common configurations is illustrated.

The book is a valuable reference for advanced graduate students working for a PhD, and for researchers and professionals in the field. A background in applied mathematics and systems and control theory is needed.

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