BOOK REVIEWS

Control and Estimation of Distributed Parameter Systems

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This volume is the Proceedings of the International Conference on Control and Estimation of Distributed Parameter Systems which took place in Vorau (Austria), from July 14 to July 20, 1996, to be the seventh in a series of conferences inaugurated in 1982. The book contains 23 refereed papers that address various important topics in optimal control and parameter identification of nonlinear dynamic systems described by partial differential equations, such as control and stability of hyperbolic systems, control and identification of parabolic systems, controllability and observability, Pontryagin's maximum principle and dynamic programming, optimal and suboptimal control, numerical solution of some of the associated problems. Recent advances in the field are described.

A brief description of the papers included follows.

Approximation Results for Parameter Estimation in Nonlinear Elastomers, by H.T. Banks and G.A. Pinter, presents theoretical convergence results for a class of parameter estimation problems in general abstract nonlinear hyperbolic systems, with applications to nonlinear elastomers used in active and passive vibration devices.

The infinite dimensional least squares parameter estimation problem is approximated by a family of finite dimensional estimation problems, and a sufficient condition for the convergence of the approximate solutions to the solution of the original problem is provided.

Preconditioners for Karush-Kuhn-Tucker Matrices Arising in the Optimal Control of Distributed Systems, by A. Battermann and M. Heinkenschloss, derives and analyses several preconditioners for very large, indefinite linear systems to be solved in interior-point methods for discretized distributed linear quadratic optimal control problems with bound constraints.

The preconditioners inherit the block structure of these linear systems, with blocks obtained from the discretization of the objective function and the governing partial differential equations. The effectiveness of the preconditioners based on some Krylov subspace methods (MINRES and SYMMLQ) is analyzed and numerical examples for an elliptic problem are shown.

Augmented Lagrangian Algorithms for State Constrained Optimal Control Problems, by M. Bergounioux and K. Kunisch, studies augmented Lagrangian algorithms, where both the state-equation and the nonsmooth state and control constraints are augmented. Convergence proofs for the proposed algorithms are given. The numerical results show that the auxiliary subproblems in the ``inner-loop" must be solved very accurately before updating the Lagrange multipliers , and that the algorithms are not too sensitive to penalty parameters.

A Priori Estimates for the Approximation of a Parabolic Boundary Control Problem, by A. Briani and M. Falcone, investigates the numerical approximation of the boundary control problem for the heat equation over a finite horizon. A priori estimates of convergence for the value function of the discrete-time problem are proven. A local version of dynamic programming is used, in order to reduce the computational complexity, and to avoid a cumbersome solution to the Hamilton-Jacobi type equation in the whole space of initial data.

On the Wellposedness of the Chaboche Model, by M. Brokate and P. Krejci, proves the local Lipschitz continuity of a multisurface stress-strain law of nonlinear kinematic hardening type within the space of time-dependent tensor-valued absolutely continuous functions, useful in rate dependent plasticity problems (where the changes in the yield surface depend on the history of the loading process).

On the Behaviour of the Value Function of a Mayer Optimal Control Problem along Optimal Trajectories, by P. Cannarsa and M.E. Tessitore, delivers an estimate on the superdifferential of the value function of an optimal problem, for a system governed by a semilinear parabolic evolution equation, along an optimal trajectory. Specifically, the dimension of the superdifferential is at most 1 along optimal trajectories.

Optimal Control Problem Governed by Semilinear Elliptic Equations with Integral Control Constraints and Pointwise State Constraints, by E. Casas, J.-P. Raymond, and H. Zidani, proves Pontryagin's maximum principle in integral form for optimal control problems governed by semilinear elliptic equations with pointwise and integral constraints. A convexity condition of the cost functional with respect to the control variable is required to establish a lower semicontinuity property of the cost functional.

Designing for Optimal Energy Absorption II, The Damped Wave Equation, by S. J. Cox, considers the wave equation in a bounded domain, with zero Dirichlet data and damping proportional to velocity, and solves the problem of minimizing, with respect to damping, the maximum, over all initial unit energy data, of the infinite time integral of the instantaneous energy. It is proven that the minimum does exist over those dampings that uniformly avoid zero and infinity. The exact minimum over the class of constant dampings is a critical point over the class of bounded dampings.

On the Approximate Controllability for Higher Order Parabolic Nonlinear Equations of Cahn-Hilliard Type, by J.I. Diaz and A.M. Ramos, proves an approximate controllability property for such equations when the nonlinearity is of sublinear type at infinity, using a fixed point argument. A counterexample shows that this property may fail when the nonlinearity is of superlinear type.

Control Problems for Parabolic Equations with State Constraints and Unbounded Control Sets, by H.O. Fattorini, derives a version of Pontryagin's maximum principle for abstract reaction-diffusion parabolic equations with pointwise or integral state constraints and unbounded control sets, using nonlinear programming theory. The results also apply to controlled Navier-Stokes equations.

Remarks on the Controllability of Some Stochastic Partial Differential Equations, by E. Fernández-Cara and J.Real, analyzes the mean-square approximate controllability and the null-controllability of a class of stochastic partial differential equations, including a stochastic heat equation and Stokes and quasi-Stokes systems. The results obtained are similar to those available for the corresponding deterministic systems.

A Reduced Basis Method for Control Problems Governed by PDEs, by K. Ito and S.S. Ravindran, describes a method for obtaining a reduced order system for control problems governed by Navier-Stokes type partial differential equations, which captures the essential properties of solutions with few basic elements (closely related to and generated by the problem being solved). This is essential, because if discretized, such equations lead to millions of state variables. Computational results for boundary temperature control and boundary electromagnetic control in channel flows are given.

Proximal Penalty Method for Ill-Posed Parabolic Optimal Control Problems, by A. Kaplan and R. Tichatschke, uses multi-step proximal regularization (with respect to the control) of a family of penalized problems, in ill-posed convex optimal control problems for linear parabolic equations with state constraints, and proves the convergence of the approximate solutions of the regularized problems to an optimal process, as well as the convergence of the corresponding values of the objective functional to the optimal value of the original problem.

On the Control of Coupled Linear Systems, by V. Komornik, P. Loreti, and E. Zuazua, proves several observability properties for coupled linear distributed systems for almost all values of the coupling parameters, for all sufficiently regular bounded domains. (Such results have previously been obtained for small enough coupling parameters). A nonharmonic analysis

combined with a compactness-uniqueness method is made.

On Dynamic Domain Decomposition of Controlled Networks of Elastic Strings and Joint-Masses, by G. Leugering, studies networks of dynamic elastic prestretched strings coupled on the vertices of the associated planar connected graph, and proves some results on well-posedness and control of such systems, using a domain decomposition based on a dynamic Steklov-Poincaré-type operator. Optimal control and exact controllability are discussed.

On a Weakly Damped System Arising in the Control of Noise, by S. Micu and E. Zuazua, investigates a simplified model for the active control of noise in a cavity, consisting of two coupled wave equations of dimensions two and one, with a dissipative term in the one-dimensional equation. The existence and uniqueness of solutions are proved, as well as the convergence of each trajectory to an equilibrium as $t \to \infty$. The convergence rate is not exponential.

Dirichlet Boundary Control of Parabolic Systems with Pointwise State Constraints, by B.S. Mordukhovich and Kaixia Zhang, studies the optimal control of linear parabolic systems with nonregular Dirichlet boundary conditions and pointwise state constraints. A general existence theorem of optimal controls is proved and necessary optimality conditions derived. The analysis is based on a penalization procedure and on investigating a parametric family of approximating problems.

Second Order Optimality Conditions and Stability Estimates for the Identification of Nonlinear Heat Transfer Laws, by A. Rösch, proves the existence of a second Fréchet derivative of the control-state mapping for the heat equation with a nonlinear function in the boundary condition, which depends only on the solution of the initial boundary-value problem, and gives a necessary second order optimality condition, based on this result. The identification problem is formulated as an optimal control problem where the unknown function is the control. It is then shown that the usual sufficient conditions for the identification problem cannot be met.

LQR Control of Shell Vibrations via Piezoceramic Actuators, by R.C.H. del Rosario and R.C. Smith, describes a model-based LQR method for controlling vibrations in cylindrical shells, using surface-mounted piezoceramic patches as actuators, which leads to unbounded control input operators. The model is abstractly stated in terms of sesquilinear forms; its well-posedness and convergence of LQR gains is proved based on analytic semigroup results combined with the LQR theory for unbounded input operators. Numerical examples demonstrate the effectiveness of the proposed method.

The Algebraic Riccati Equation in Discrete and Continuous Time, by O. J. Staffans, analyzes the similarities and differences between discrete- and continuous-time algebraic Riccati equations for infinite-dimensional optimization problems with bounded or `"sufficiently" unbounded control and observation operators. Specifically, discrete- and continuous-time Riccati equations resemble significantly with one another for unbounded operators.

The Wave Equation with Neuman Controls: On Lions's F Space, by D. Tataru, proposes a solution to reconcile the two opposite criteria for ensuring regularity for the space of controls: this space should be large enough for enabling controllability, and small enough for preserving the initial regularity of solutions.The solution is provided for the wave equation with Neuman controls.

On the Pointwise Stabilization of a String, by M. Tucsnak, proves some results for an initial and boundary value problem described by the one-dimensional wave equation with damping concentrated at an interior point. It is shown that the decay rate is uniform for regular initial data, and lower estimates of the decay rate are given.

Exact Controllability of the Generalized Boussinesq Equation, by Bing-Yu Zhang, considers distributed control of a system described by the generalized Boussinesq equation on a periodic domain, the unit circle in the plane. It is shown that the system is globally exactly controllable with a local control, if the control is allowed to act on the whole domain (or on a sub-domain only, provided the initial and terminal states have "small amplitude" in a certain sense).

Written in the standard mathematical theorem-proof style, the book makes an important theoretical contribution. Numerical algorithms suggested for the solution of some control theoretical problems, are sometimes included, and their convergence properties analyzed. There are rather few numerical examples, which refer

to industrially relevant applications. Each paper ends with references to the literature.

The intended audience is that of mathematicians, control theorists and researchers, seeking for information on the latest advances in the distributed parameter systems field. By its broad coverage, good organization, the theoretical results included, and the highlighted potential applications, the reviewed book recommends itself as an advanced, supplementary reading in mathematical system theory for partial differential equations.

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