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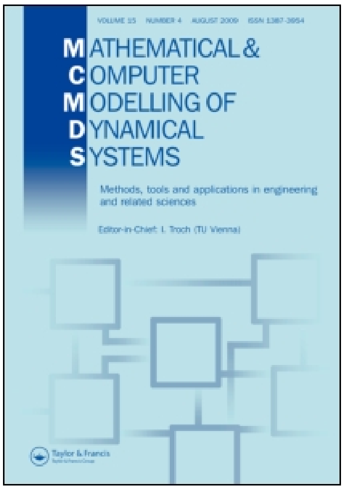

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Modelling of distributed-parameter systems for control purposes

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EDITORIAL

Modelling of distributed-parameter systems for control purposes

Thirty years ago, control design was mainly based on linear finite-dimensional models sometimes closely but more often less closely connected to the real character of the plant. In many applications, these linear controllers are sufficient in terms of accuracy and dynamic performance and hence are still common in industry. If the plant under consideration exhibits significant nonlinearities and/or has a distributed-parameter structure, an increase in the performance of the closed-loop system can only be achieved by taking into account the real nature of the system to be controlled. Beginning in the 80s, modern control methods were introduced to systematically account for the essential nonlinearities in the control design process for lumped-parameter nonlinear systems. Since that time a variety of model-based nonlinear control design techniques have been developed, among which the sliding mode control, the passivity-based design approach, backstepping, differential geometric methods, the flatness-based control and many others can be found. Nowadays, the application of nonlinear control design methods is even standard in many industrial applications. Clearly, apart from the advances in control theory, the availability of modern computer programs for numeric and symbolic computation, together with the steadily increasing power of automation hardware being used in real-time applications, make the practical use of these modern control concepts possible.

Usually, the so-called early lumping approach is used in control engineering practice if one deals with distributed-parameter systems (DPSs), i.e. their mathematical models are given in the form of partial differential equations. Thereby, the DPS is reduced to a system of (nonlinear) ordinary differential equations by means of Galerkin or Rayleigh-Ritz approximation, finite-difference or finite-element schemes or by other model approximation techniques. Thus, the distributed-parameter nature of the system is not fully taken into account in a systematic way. In this case, it is well known that the performance of the resulting closed-loop system may be degraded, or in the worst case, the system can even be destabilized. Therefore, in the last years the control community has made much effort to extend certain concepts known from finite-dimensional control theory to the distributed-parameter case. Within the so-called late lumping approach, the controller is directly designed on the basis of the distributed-parameter model and the control law is then (numerically) approximated for the purpose of implementation on the real system. In general, it turns out that an appropriate formulation of the mathematical model of distributed-parameter systems drastically simplifies the subsequent control design task.

This special issue is concerned with this latter aspect where we aim at presenting theoretical and practical results in the modelling of distributed-parameter systems in view of a subsequent controller design. The papers are based on selected contributions that were presented in a special session of the 5th MATHMOD conference in February 2006, Vienna, Austria.

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The first contribution by M. Schöberl, H. Ennsbrunner and K. Schlacher, with the title Modelling of Piezoelectric Structures - A Hamiltonian Approach, is devoted to the extension of the class of port-Hamiltonian systems, well established for the modelling and control of lumped-parameter systems, to the distributed-parameter case exemplified by means of piezoelectric structures. Thereby, the authors place emphasis on the derivation of a formal geometric representation of distributed-parameter port-Hamiltonian systems which preserves certain useful properties known from the lumped-parameter case. The second paper Port based Modelling of a Multiscale Adsorption Column by A. Baaiu, F. Couenne, Y. Le Gorrec, L. Lefevre and M. Tayakout presents the application of port-based modelling (bond graphs) techniques to a distributed-parameter chemical process. The coupling between the different scales of the distributed-parameter process under consideration is described by means of a power conserving interconnection structure, named Dirac structure. The third paper with the title Model Inversion of Boundary Controlled Parabolic Partial Differential Equations Using Summability Methods by T. Meurer and M. Zeitz is concerned with the design of a feedforward tracking controller for a boundary controlled diffusion-convection-reaction model with nonlinear reaction rate. A formal power series is used to parameterize all system quantities (states and input) in terms of a so-called basic (flat) output. To enhance the convergence properties of the series being involved, special summability methods based on the k-summation technique are proposed. The fourth contribution by T. Kreuzinger, M. Bitzer and W. Marquardt with the title Mathematical Modelling of a Domestic Heating System with Stratified Storage Tank deals with the derivation of a hybrid model of a heating system for hot water. This model combines a finite-state automaton, representing the discrete-event dynamics, with distributed-parameter models for the heat exchanger, the burner and the storage tank, representing the continuous-time dynamics. For the latter models, different spatial discretization schemes based on the method of lines are investigated in terms of feasibility and numerical efficiency. The last paper An Analytical Approach for Modelling Asymmetrical Hot Rolling of Heavy Plates by T. Kiefer and A. Kugi presents the derivation of an online executable mathematical model for describing the so-called front end bending phenomenon, which often occurs in hot rolling of heavy plates due to asymmetries in the roll gap. A semi-analytical approach based on the upper bound theorem for ideal rigid-plastic materials is utilized to derive two models with different complexity, one more detailed model taking into account the exact geometry of the plastic deformation zone and one simplified model exploiting the analogy of rolling and flat compression.

Finally, we would like to thank all authors for their excellent contributions to this special issue. We hope that the interested reader can be convinced that suitable modelling techniques are necessary when we want to advantageously exploit the structure of distributed-parameter systems within the controller and observer design as well as for online optimization and identification purposes.

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