

# Preface

The complexity and dynamic order of controlled engineering systems is constantly increasing. Complex large scale dynamic systems – where “large” reflects the system’s order and not necessarily its physical size – appear in many engineering fields, such as, aerospace, micro-electro-mechanics, manufacturing, civil engineering and power systems. Modeling of these systems often results in high-order models imposing great challenges to their analysis, design, and feedback control. This edited volume is aimed at providing comprehensive contributions on recent analytical and computational methods for addressing the model reduction, performance analysis, and feedback control design of such systems. The book presents new theoretical developments, computational approaches, and illustrative applications to various fields. The scope of the book is intended to be interdisciplinary emphasizing the commonality and applicability of the methods to various fields.

The book comprises 12 chapters.

The first chapter, by A.C. Antoulas, C.A. Beattie, and S. Gugercin, presents a detailed and thorough exposition of interpolatory model order reduction methods for large-scale systems. Roughly speaking, these methods seek to obtain reduced-order models whose transfer function interpolates that of the original system at selected interpolation points in the frequency domain along selected input or output tangent directions. The question of the selection of interpolation points and tangential directions is examined in the context of meeting desired approximation goals. Finally, the methods are applied to systems with a generalized coprime factorization (such as second-order systems and systems with delays) and systems with a structured dependence on parameters that need to be retained in the reduced-order model. Examples from various disciplines conclude the chapter.

The chapter by R. Colgren examines the efficient model reduction of large-scale systems for control design. The motivation is based on meeting computational requirements for control and meeting practical implementation constraints of full-order dynamic controllers. A summary of the evolution of model reduction methods for control is presented with an emphasis on approaches that are easily applicable to large generalized models obtained by Computer Aided Design (CAD) and Finite Element Analysis (FEA) tools. A large-scale model of an air vehicle with significant aero-servo-elastic coupling is used to illustrate the methods.

The chapter by M.C. de Oliveira and A.S. Wroldsen presents a thorough study of the dynamic modeling and simulation of large tensegrity structural systems. Tensegrity structures are composed of just rods and strings, so that the rods are in compression and the strings in tension. Such large tensegrity systems can find applications as lightweight, deployable, and shape controllable structures. The authors derive the dynamic models for a general Class  $k$  tensegrity system and examine the implementation of these models in a computer simulation environment.

The chapter by X. Dai, T. Breikin, H. Wang, G. Kulikov, and V. Arkov investigates the data-driven reduced-order modeling of gas turbine engines for the purpose of on-board condition monitoring and fault detection. Model-based condition monitoring relies on the long-term predictive capabilities of reduced-order models that are compatible with limited on-board computational resources. A data-driven reduced-order model development is presented for gas turbine systems based on dynamic nonlinear least-squares identification. Methods to accelerate the speed of the identification algorithm are proposed using iterative calculation of the gradient and Hessian approximation. Data gathered in an aero-engine test bed are used to illustrate the reduced-order modeling approach.

The chapter by J. Lavaei, S. Sojoudi, and A.G. Aghdam examines the robust controllability and observability of a large-scale uncertain system with the objective of selecting dominant inputs and outputs to obtain a simplified control structure. The problem is formulated as the minimization of the smallest singular value of the corresponding Gramian in a polynomial uncertain system. It is shown that for such a system the Gramian is a rational function that can be approximated by a matrix polynomial. Subsequently, sum-of-squares (SoS) optimization techniques are employed for efficient computational solution, and simulation studies are used to validate the effectiveness of the proposed results.

The chapter by P. Krishnamurthy and F. Khorrami addresses the decentralized output feedback control of a class of interconnected nonlinear uncertain large-scale systems using a dynamic high-gain scaling approach. The method provides a unified framework for observer/controller design based on the solution of coupled state-dependent Lyapunov inequalities. Stability and disturbance attenuation of the proposed decentralized control solution are discussed in the input-to-output practical stability and integral-input-to-output practical stability frameworks.

The chapter by J. Xiong, V.A. Ugrinovskii, and I.R. Petersen examines the guaranteed-cost output feedback control problem for a class of large-scale uncertain stochastic systems with random parameters. It is assumed that the system uncertainties satisfy integral quadratic constraints and the random parameters follow a Markov process. Sufficient conditions are derived for decentralized controller synthesis that guarantees stability and a suboptimal level of quadratic performance. The control law uses local, in general non-Markovian, subsystem outputs and local subsystem operation modes to produce local subsystem control actions. Design conditions are provided in terms of rank constrained linear matrix inequalities (LMIs).

The chapter by M.S. Stankovic, D.M. Stipanovic, and S.S. Stankovic presents novel algorithms for decentralized overlapping control of large-scale complex systems. The approach is based on multiagent networks in which the agents utilize

dynamic consensus strategies to reach the agreement upon their actions. Different decentralized control structures are proposed and different algorithms are derived depending on the local control laws implemented by the agents. Properties and performance of the algorithms are discussed and an application is presented to the decentralized control of formations of unmanned aerial vehicles (UAVs).

The chapter by D. Zelazo and M. Mesbahi develops a network-centric analysis and synthesis framework for certain classes of large-scale interconnected systems. The systems under consideration involve linear dynamic subsystems that interact with other subsystems via an interconnection topology. The chapter examines the controllability and observability of such networked systems and investigates the network performance with respect to its  $\mathcal{H}_2$  system norm. The effect of the structural properties of the network interconnection on its controllability, observability, and  $\mathcal{H}_2$  norm performance are delineated. An algorithm for synthesizing optimal networks in the  $\mathcal{H}_2$  system norm setting is presented.

The chapter by R.R. Negenborn, G. Hug-Glanzmann, B. De Schutter, and G. Andersson, illustrates a novel coordination strategy for coordinating multiple control agents that control overlapping subnetworks in a network. The motivation stems from the distributed control of large-scale power networks. A simulation study on an adjusted IEEE 57-bus power network with Flexible Alternating Current Transmission Systems (FACTS) devices as controlled entities is used to validate the coordination strategy.

The chapter by J. Rice, P. Massioni, T. Keviczky, and M. Verhaegen, examines recently developed distributed control techniques for designing controllers for large-scale systems with sparse structure. The methods rely on the structural properties of the system and the associated control problem by assuming a sequentially semiseparable, decomposable, or identical subsystem architecture. A benchmark problem of the control of an infinite-dimensional car platoon in an  $\mathcal{H}_2$  norm setting is used for a comparative study of the proposed methods.

The chapter by M. Meisami-Azad, J. Mohammadpour-Velni, K. Hiramoto, and K.M. Grigoriadis, investigates the integrated plant parameter and control parameter design in controlled large-scale structural systems. The objective is to integrate the structural parameter and the controller gain design steps to achieve an improved final design. To this end, an explicit upper bound of the  $\mathcal{H}_2/\mathcal{H}_\infty$  norm of a collocated structural system is developed along with a parameterization of output feedback gains that guarantee such bounds. The proposed bounds are subsequently used in a convex optimization framework to design structural damping parameters and feedback control gains that meet closed-loop performance specifications.

We thank Steven Elliot, Senior Editor – Engineering in Springer for his assistance and most importantly the authors of the individual chapters for their contribution to this effort.

Houston, TX  
May 2010

*Javad Mohammadpour*  
*Karolos M. Grigoriadis*

Efficient Modeling and Control of Large-Scale Systems

Mohammadpour, J.; Grigoriadis, K.M. (Eds.)

2010, XX, 335 p., Hardcover

ISBN: 978-1-4419-5756-6