Model Order Reduction Techniques With Applications In Finite Element Ysis

Dynamical systems are a principal tool in the modeling, prediction, and control of a wide range of complex phenomena. As the need for improved accuracy leads to larger and more complex dynamical systems, direct simulation often becomes the only available strategy for accurate prediction or control, inevitably creating a considerable burden on computational resources. This is the main context where one considers model reduction, seeking to replace large systems of coupled differential and algebraic equations that constitute high fidelity system models with substantially fewer equations that are crafted to control the loss of fidelity that order reduction may induce in the system response. Interpolatory methods are among the most widely used model reduction techniques, and Interpolatory Methods for Model Reduction is the first comprehensive analysis of this approach available in a single, extensive resource. It introduces state-of-the-art methods reflecting significant developments over the past two decades, covering both classical projection frameworks for model reduction and data-driven, nonintrusive frameworks. This textbook is appropriate for a wide audience of engineers and other scientists working in the general areas of large-scale dynamical systems and data-driven modeling of dynamics. Model order reduction (MOR) techniques reduce the complexity of VLSI designs, paving the way to higher operating speeds and smaller feature sizes. This 2007 book presents a systematic introduction to, and treatment of, the key

MOR methods employed in general linear circuits, using real-world examples to illustrate the advantages and disadvantages of each algorithm. Following a review of traditional projection-based techniques, coverage progresses to more advanced MOR methods for VLSI design, including HMOR, passive truncated balanced realization (TBR) methods, efficient inductance modeling via the VPEC model, and structure-preserving MOR techniques. Where possible, numerical methods are approached from the CAD engineer's perspective, avoiding complex mathematics and allowing the reader to take on real design problems and develop more effective tools. With practical examples and over 100 illustrations, this book is suitable for researchers and graduate students of electrical and computer engineering, as well as practitioners working in the VLSI design industry.
Data-driven discovery is revolutionizing the modeling, prediction, and control of complex systems. This textbook brings together machine learning, engineering mathematics, and mathematical physics to integrate modeling and control of dynamical systems with modern methods in data science. It highlights many of the recent advances in scientific computing that enable data-driven methods to be applied to a diverse range of complex systems, such as turbulence, the brain, climate, epidemiology, finance, robotics, and autonomy. Aimed at advanced undergraduate and beginning graduate students in the engineering and physical sciences, the text presents a range of topics and methods from introductory to state of the art.
This monograph addresses the state of the art of reduced order methods for modeling and computational reduction of complex parametrized systems, governed by ordinary and/or

partial differential equations, with a special emphasis on real time computing techniques and applications in computational mechanics, bioengineering and computer graphics. Several topics are covered, including: design, optimization, and control theory in real-time with applications in engineering; data assimilation, geometry registration, and parameter estimation with special attention to real-time computing in biomedical engineering and computational physics; real-time visualization of physics-based simulations in computer science; the treatment of high-dimensional problems in state space, physical space, or parameter space; the interactions between different model reduction and dimensionality reduction approaches; the development of general error estimation frameworks which take into account both model and discretization effects. This book is primarily addressed to computational scientists interested in computational reduction techniques for large scale differential problems.

7th International Conference, Braunschweig, Germany, July 13–16, 2020, Proceedings

Machine Learning, Dynamical Systems, and Control

Approximation of Large-Scale Dynamical Systems

Model Order Reduction Techniques for the Optimal Control of Parabolic Partial Differential Equations with Control and State Constraints

Model Reduction and Approximation

In the past decades, model reduction has become an ubiquitous tool in analysis and simulation of dynamical systems, control design, circuit simulation, structural dynamics, CFD, and many other disciplines dealing with complex physical models. The aim of this book is to

survey some of the most successful model reduction methods in tutorial style articles and to present benchmark problems from several application areas for testing and comparing existing and new algorithms. As the discussed methods have often been developed in parallel in disconnected application areas, the intention of the mini-workshop in Oberwolfach and its proceedings is to make these ideas available to researchers and practitioners from all these different disciplines.

The objective of this thesis is to develop and analyze model order reduction approaches for the efficient integration of parametrized mathematical models and experimental measurements. Model Order Reduction (MOR) techniques for parameterized Partial Differential Equations (PDEs) offer new opportunities for the integration of models and experimental data. First, MOR techniques speed up computations allowing better explorations of the parameter space. Second, MOR provides actionable tools to compress our prior knowledge about the system coming from the parameterized best-knowledge model into low-dimensional and more manageable forms. In this thesis, we demonstrate how to take advantage of MOR to design computational methods for two classes of problems in data assimilation. In the first part of the thesis, we discuss and extend the Parametrized-Background Data-Weak (PBDW) approach for state estimation. PBDW combines a parameterized best knowledge mathematical model and experimental data to rapidly estimate the system state over the domain of interest using a small number of local measurements. The approach relies on projection-by-data, and exploits model reduction techniques to encode the knowledge of the parametrized model into a linear space appropriate for real-time evaluation. In this work, we extend the PBDW formulation in three ways. First, we develop an experimental a posteriori estimator for the error in the state. Second, we develop computational procedures to construct local approximation spaces in subregions of the computational domain in which the best-knowledge model is defined. Third, we present an adaptive strategy to handle experimental noise in the observations. We apply our approach to a companioni heat transfer experiment to prove the effectiveness of our technique. In the second part of the thesis, we present a model-order reduction approach to simulation based classification, with particular application to Structural Health Monitoring (SHM). The approach exploits (i) synthetic results obtained by repeated solution of a parametrized PDE for different values of the parameters, (ii) machine-learning algorithms to generate a classifier that monitors the state of damage of the system, and (iii) a reduced basis method to reduce the computational burden associated with the model evaluations. The approach is based on an offline/online computational decomposition. In the offline stage, the fields associated with many different system configurations, corresponding to different states of damage, are computed and then employed to teach a classifier. Model reduction techniques, ideal for this manyquery context, are employed to reduce the computational burden associated with the parameter exploration. In the online stage, the classifier is used to associate measured data to the relevant diagnostic class. In developing our approach for SHM, we focus on two specific aspects. First, we develop a mathematical formulation which properly integrates the parameterized PDE model within the classification problem. Second, we present a sensitivity analysis to take into account the error in the model. We illustrate our method and we demonstrate its effectiveness through the vehicle of a particular companion experiment, a harmonically excited microtruss.

The objective of this work is to develop a method which solves the nonlinear elastohydrodynamic contact problem in a fast and precise way using model order reduction techniques. The reduction procedure is based on a projection onto a low-dimensional subspace using different hyper-reduction procedures. The method provides fast and highly accurate reduced order models for stationary and transient, Newtonian and Non-Newtonian EHD line and point contact problems. This work was published by Saint Philip Street Press pursuant to a Creative Commons license permitting commercial use. All rights not granted by the work's license are retained by the author or authors.

Designing complex integrated circuits relies heavily on mathematical methods and calls for suitable simulation and optimization tools. The current design approach involves simulations and optimizations in different physical domains (device, circuit, thermal, electromagnetic) and in a range of electrical engineering disciplines (logic, timing, power, crosstalk, signal integrity, system functionality). COMSON was a Marie Curie Research Training Network created to meet these new scientific and training challenges by (a) developing new descriptive models that take these mutual dependencies into account, (b) combining these models with existing circuit descriptions in new simulation strategies and (c) developing new optimization techniques that will accommodate new designs. The book presents the main project results in the fields of PDAE modeling and simulation, model order reduction techniques and optimization, based on merging the know-how of three major European semiconductor companies with the combined expertise of university groups specialized in developing suitable mathematical models, numerical schemes and e-learning facilities. In addition, a common Demonstrator Platform for testing mathematical methods and approaches was created to assess whether they are capable of addressing the industry ' s problems, and to educate young researchers by providing hands-on experience with state-of-the-art problems.

Model Order Reduction Techniques with Applications in Electrical Engineering

Mathematical Software – ICMS 2020

Model Order Reduction Techniques for Circuit Simulation

Model Order Reduction Techniques for Uncertainty

Quantification Problems

Machine Learning for Model Order Reduction

The idea for this book originated during the workshop "Model order reduction, coupled problems and optimization" held at the Lorentz Center in Leiden from S- tember 19 – 23, 2005. During one of the discussion sessions, it became clear that a book describing the state of the art in model order reduction, starting from the very basics and containing an overview of all relevant techniques, would be of great use for students, young researchers starting in the ?eld, and experienced researchers. The observation that most of the theory on model order reduction is scattered over many good papers, making it dif?cult to ?nd a good starting point, was supported by most of the participants. Moreover, most of the speakers at the workshop were willing to contribute to the book that is now in front of you. The goal of this book, as de?ned during the discussion sessions at the workshop, is three-fold: ?rst, it should describe the basics of model order reduction. Second, both general and more specialized model order reduction techniques for linear and nonlinear systems should be covered, including the use of several related numerical techniques. Third, the use of model order reduction techniques in practical appli- tions and current research aspects should be discussed. We have organized the book according to these goals. In Part I, the rationale behind model order reduction is explained, and an overview of the most common methods is described.

Many physical, chemical, biomedical, and technical processes can be described by partial differential equations or dynamical systems. In spite of increasing computational capacities, many problems are of such high complexity that they are solvable only with severe simplifications, and the design of efficient numerical schemes remains a central research challenge. This book presents a tutorial introduction to recent developments in mathematical methods for model reduction and approximation of complex systems. Model Reduction and Approximation: Theory and Algorithms contains three parts that cover (I) sampling-based methods, such as the reduced basis method and proper orthogonal decomposition, (II) approximation of high-dimensional problems by low-rank tensor techniques, and (III) system-theoretic methods, such as balanced truncation, interpolatory methods, and the Loewner framework. It is tutorial in nature, giving an accessible introduction to state-of-the-art model reduction and approximation methods. It also covers a wide range of methods drawn from typically distinct communities (sampling based, tensor based, system-theoretic).?? This book is intended for researchers interested in model reduction and approximation, particularly graduate students and young researchers.

This book constitutes the proceedings of the 7th International Conference on Mathematical Software, ICMS 2020, held in Braunschweig, Germany, in July 2020. The 48 papers included in this volume were carefully reviewed and selected from 58 submissions. The program of the 2020 meeting consisted of 20 topical sessions, each of which providing an overview of the challenges, achievements and progress in a environment of mathematical software research, development and use.

An increasing complexity of models used to predict real-world systems leads to the need for algorithms to replace complex models with far simpler ones, while preserving the accuracy of the predictions. This two-volume handbook covers methods as well as applications. This first volume focuses on real-time control theory, data assimilation, real-time visualization, high-dimensional state spaces and interaction of different reduction techniques.

Model Order Reduction Techniques for PEEC Modeling of RF & High-speed Multi-layer Circuits

Interpolatory Methods for Model Reduction

State of the Art in Scientific Computing

Advanced Model Order Reduction Techniques in VLSI Design

Snapshot-Based Methods and Algorithms

This contributed volume presents some of the

latest research related to model order reduction of complex dynamical systems with a focus on time-dependent problems. Chapters are written by leading researchers and users of model order reduction techniques and are based on presentations given at the 2019 edition of the workshop series Model Reduction of Complex Dynamical Systems – MODRED, held at the University of Graz in Austria. The topics considered can be divided into five categories: system-theoretic methods, such as balanced truncation, Hankel norm approximation, and reduced-basis methods; data-driven methods, including Loewner matrix and pencil-based approaches, dynamic mode decomposition, and kernel-based methods; surrogate modeling for design and optimization, with special emphasis on control and data assimilation; model reduction methods in applications, such as control and network systems, computational electromagnetics, structural mechanics, and fluid dynamics; and model order reduction software packages and benchmarks. This volume will be an ideal resource for graduate students and researchers in all areas of model reduction, as well as those working in applied mathematics and theoretical informatics.
This thesis investigates the frequency weighted balanced model reduction problem for linear time invariant systems. First, an interesting property of well-known frequency weighted balanced model reduction techniques (Enns', Lin and Chiu's, Wang

et al's, Varga and Anderson's), is derived with special types of weighting functions. The special functions considered here are co-inner and inner functions, for input and output weights respectively. The derivations are carried out for both continuous-time and discrete-time systems. The results are then illustrated using numerical examples. Two new frequency weighted balanced model reduction techniques, based on partial fraction expansion idea, are then developed. These methods yield stable models even when two sided weightings are applied. A priori error bounds for the model reduction methods are derived. Lower weighted errors and error bounds are obtained using free parameters. The results are then illustrated using several numerical examples, including those involving practical applications to show the e ectiveness of the methods. We then proceed with an alternative frequency weighted balanced model reduction method which is based on Schur decomposition. This method yields a sigini cant improvement on Lin and Chiu's technique. Two a priori error bounds for the model reduction method are derived. Lower approximation errors and error bounds are obtained using free parameters. Finally, the results are illustrated using several numerical examples including those involving robot controller reduction applications.

The papers in this volume start with a description of the construction of reduced models through a

review of Proper Orthogonal Decomposition (POD) and reduced basis models, including their mathematical foundations and some challenging applications, then followed by a description of a new generation of simulation strategies based on the use of separated representations (space-parameters, space-time, space-time-parameters, space-space,...), which have led to what is known as Proper Generalized Decomposition (PGD) techniques. The models can be enriched by treating parameters as additional coordinates, leading to fast and inexpensive online calculations based on richer offline parametric solutions. Separated representations are analyzed in detail in the course, from their mathematical foundations to their most spectacular applications. It is also shown how such an approximation could evolve into a new paradigm in computational science, enabling one to circumvent various computational issues in a vast array of applications in engineering science.
Despite the continued rapid advance in computing speed and memory the increase in the complexity of models used by engineers persists in outpacing them. Even where there is access to the latest hardware, simulations are often extremely computationally intensive and time-consuming when full-blown models are under consideration. The need to reduce the computational cost involved when dealing with high-order/many-degree-of-freedom models can be offset by adroit computation. In this light, model-reduction methods

have become a major goal of simulation and modeling research. Model reduction can also ameliorate problems in the correlation of widely used finite-element analyses and test analysis models produced by excessive system complexity. Model Order Reduction Techniques explains and compares such methods focusing mainly on recent work in dynamic condensation techniques: - Compares the effectiveness of static, exact, dynamic, SEREP and iterative-dynamic condensation techniques in producing valid reduced-order models; - Shows how frequency shifting and the number of degrees of freedom affect the desirability and accuracy of using dynamic condensation; - Answers the challenges involved in dealing with undamped and non-classically damped models; - Requires little more than first-engineering-degree mathematics and highlights important points with instructive examples. Academics working in research on structural dynamics, MEMS, vibration, finite elements and other computational methods in mechanical, aerospace and structural engineering will find Model Order Reduction Techniques of great interest while it is also an excellent resource for researchers working on commercial finite-element-related software such as ANSYS and Nastran.
Model Reduction of Parametrized Systems
Index-aware Model Order Reduction Methods
Finite Element Modeling of Elastohydrodynamic Lubrication Problems

Proceedings of a Workshop held in Oberwolfach, Germany, October 19-25, 2003

An Introduction

An increasing complexity of models used to predict real-world systems leads to the need for algorithms to replace complex models with far simpler ones, while preserving the accuracy of the predictions. This two-volume handbook covers methods as well as applications. This second volume focuses on applications in engineering, biomedical engineering, computational physics and computer science.

This book constitutes the refereed proceedings of the 7th International Conference on Applied Parallel Computing, PARA 2004, held in June 2004. The 118 revised full papers presented together with five invited lectures and 15 contributed talks were carefully reviewed and selected for inclusion in the proceedings. The papers are organized in topical sections.

"In this thesis, a number of new reduction techniques were developed in order to address the key shortcomings of current model order reduction methods. Specifically a new approach for handling macromodels with a very large number of ports was developed, a multi-level reduction and sprasification method was proposed for regular as well as parametric macromodels, and finally a new time domain reduction method was presented for the macromodeling of nonlinear parametric systems. Using these approaches, CPU speedups of 1 to 2 orders of magnitude were obtained." --

Doctoral Thesis / Dissertation from the year 2012 in the subject Engineering - General, Basics, grade: A, Anna University, language: English, abstract: The analysis and synthesis of higher order models are complicated and are not desirable on economic and computational considerations. To circumvent the difficulties, lower order model formulation techniques are utilized to find a lower dimensional approximant for the original higher order model. The obtained lower order model preserves the characteristics of the original higher order model. Firstly, the linear time invariant single input single output continuous systems are considered to investigate the efficiency of the proposed lower order model formulation approach. For this, the given linear time invariant higher order system represented in the form of transfer function is adopted to get adjunct lower order transfer function and its coefficients are tuned suitably with the help of modified particle swarm optimization along with transient and steady state gain adjustments. The lower order model is formed on an error based criterion. Moreover, the formulated second order models are used to design the continuous PID controllers. Secondly, the single input single output linear time invariant discrete systems are dealt for model order formulation with the help of proposed approach. Discrete PID controllers are designed by employing the proposed formulated lower order model and it retains the desired performance specifications. The lower order models minimize the computational complexities for the process of output stabilization compared with higher order models. The proposed approach is direct and simple in approach for linear time invariant discrete systems. Thirdly, certain procedures are proposed for designing the state feedback controller and state space observer of linear time invariant continuous and discrete systems. Further, the lower order model formulation approach for single input single output systems is extended to multi input multi output linear time invariant continuous and discrete systems. The analysis of the discrete system is carried out directly without applying any linear or bilinear transformations, which reduces computational complexities. This approach guarantees an absolutely stable lower order model if the considered higher order system is stable in nature. The proposed methodology extracts a second order model which has a better approximation compared to models obtained due to other methods. Algorithms are also presented for all the contributions provided in the thesis with illustrations and results.

Data-Driven Science and Engineering

Applied Parallel Computing

Fundamentals and Applications

State Estimation and Structural Health Monitoring

Theory and Algorithms

The main aim of this book is to discuss model order reduction (MOR) methods for differential-algebraic equations (DAEs) with linear coefficients that make use of splitting techniques before applying model order reduction. The splitting produces a system of ordinary differential equations (ODE) and a system of algebraic equations, which are then reduced separately. For the reduction of the ODE system, conventional MOR methods can be used, whereas for the reduction of the algebraic systems new methods are discussed. The discussion focuses on the index-aware model order reduction method (IMOR) and its variations, methods for which the so-called index of the original model is automatically preserved after reduction.

Model Order Reduction Techniqes focuses on model reduction problems with particular applications in electrical engineering. Starting with a clear outline of the technique and their wide methodological background, central topics are introduced including mathematical tools, physical processes, numerical computing experience, software developments and knowledge of system theory. Several model reduction algorithms are then discussed. The aim of this work is to give the reader an overview of reduced-order model design and an operative guide. Particular attention is given to providing basic concepts for building expert systems for model reducution.

This book provides a basic introduction to reduced basis (RB) methods for problems involving the repeated solution of partial differential equations (PDEs) arising from engineering and applied sciences, such as PDEs depending on several parameters and PDE-constrained optimization. The book presents a general mathematical formulation of RB methods, analyzes their fundamental theoretical properties, discusses the related algorithmic and implementation aspects, and highlights their built-in algebraic and geometric structures. More specifically, the authors discuss alternative strategies for constructing accurate RB spaces using greedy algorithms and proper orthogonal decomposition techniques, investigate their approximation properties and analyze offline-online decomposition strategies aimed at the reduction of computational complexity. Furthermore, they carry out both a priori and a posteriori error analysis. The whole mathematical presentation is made more stimulating by the use of representative examples of applicative interest in the context of both linear and nonlinear PDEs. Moreover, the inclusion of many pseudocodes allows the reader to easily implement the algorithms illustrated throughout the text. The book will be ideal for upper undergraduate students and, more generally, people interested in scientific computing. All these pseudocodes are in fact implemented in a MATLAB package that is freely available at https://github.com/redbkit

This thesis investigates the frequency weighted balanced model order reduction problem for linear time invariant systems. First, two new frequency weighted balanced truncation techniques based on zero crossterms are proposed. Both methods are applicable for single-sided weighting, and are based on modifications to Sreeram and Sahlan's technique. The first method uses the properties of all-pass function to transform the original frequency weighted model order reduction problem into an equivalent unweighted model reduction problem, while in the second method, the relationship between the final and the intermediate reduced order model used in Sreeram and Sahlan's technique is derived. Numerical examples show that a significant error reduction can be achieved using both methods. Second, we present an improvement to frequency weighted balanced truncation technique based on well-known partial fraction expansion idea. The method yields stable reduced-order models for double-sided weightings. Two numerical examples including a practical application example, show a significant improvement over the other well-known techniques. Lastly, we present passivity preserving frequency-weighted model order reduction techniques for general large-scale RLC (resistor-inductor-capacitor) systems. Three well-known frequency weighted balanced truncation techniques (Enns', Wang et al.'s and Lin and Chiu's), which preserve only stability and not passivity are generalized to include passivity. Conditions under which the passivity is preserved are also derived. Four practical examples are given to show the validity and effectiveness of the proposed algorithms using different weighting functions.

System- and Data-Driven Methods and Algorithms

On the Use of Model Order Reduction Techniques for the Elastohydrodynamic Contact Problem

Dimension Reduction of Large-Scale Systems

Coupled Multiscale Simulation and Optimization in Nanoelectronics
Application of Model Order Reduction Techniques in PID controller Design
ECM2 is a completely updated and expanded Second Edition of the well-established Encyclopedia of Computational Mechanics. The project has once again been prepared under the guidance of three of the world’s foremost experts in the field: Erwin Stein, Professor Emeritus, Stein Institut für Baumechanik und Numerische Mechanik, Leibniz Universität, Hannover, Germany René de Borst, Centenary Professor of Civil Engineering, University of Sheffield, UK Thomas J. R. Hughes, Peter O'Donnell Jr. Chair in Computational and Applied Mathematics and Professor of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin, TX USA Though following the same structure as the first edition, ECM2 has been expanded from three to six volumes with the subjects "Fundamentals" in Volumes 1 & 2, "Solids and Structures" in Volumes 3 & 4, and "Fluids" in Volumes 5 & 6. It is published both in print and on line. Volumes 1 & 2, Fundamentals , contain contributions related to mathematics, mechanics, and computer science, and are structured as discretization methods, treating approximations with finite differences, discrete variational forms, boundary integral equations and further problem-oriented techniques, and the generation and visualization of geometry;

meshes and results; various direct and iterative solvers; and time-dependent problems. Volumes 3 & 4, Solids and Structures , are organized into five different parts, namely, structural behavior; constitutive theories and their implementation; materials and processing; interaction problems; and identification, stochastics, and optimization. Volumes 5 & 6, Fluids, builds on the fundamentals described in Volumes 1 & 2. The chapters in Volumes 5 & 6 fall within four main groupings. The first grouping includes chapters describing additional basic methodologies used in computational fluid dynamics. The second comprises chapters on various aspects of incompressible viscous flows. The third part focuses on compressible fluid dynamics. The fourth pertains to problems involving moving domains and free surfaces, and application areas. With contributions from more than 50 leading experts drawn from around the globe, this is an essential and comprehensive reference for any university engineering department or corporation, containing must-have, up-to-date content of huge value to researchers, students and practitioners alike.

An increasing complexity of models used to predict real-world systems leads to the need for algorithms to replace complex models with far simpler ones, while preserving the accuracy of the predictions. This three-volume handbook covers methods as well as applications. This third volume focuses on applications in engineering, biomedical engineering, computational physics and computer science.

This Book discusses machine learning for model order reduction, which can be used in modern VLSI design to predict the behavior of an electronic circuit, via mathematical models that predict behavior. The author describes techniques to reduce significantly the time required for simulations involving large-scale ordinary differential equations, which sometimes take several days or even weeks. This method is called model order reduction (MOR), which reduces the complexity of the original large system and generates a reduced-order model (ROM) to represent the original one. Readers will gain in-depth knowledge of machine learning and model order reduction concepts, the tradeoffs involved with using various algorithms, and how to apply the techniques presented to circuit simulations and numerical analysis. Introduces machine learning algorithms at the architecture level and the algorithm levels of abstraction; Describes new, hybrid solutions for model order reduction; Presents machine learning algorithms in depth, but simply; Uses real, industrial applications to verify algorithms.

These days, computer-based simulation is considered the quintessential approach to exploring new ideas in the different disciplines of science, engineering and technology (SET). To perform simulations, a physical system needs to be modeled using mathematics; these models are often represented by linear time-invariant (LTI) continuous-time (CT) systems. Oftentimes these systems are subject to additional algebraic constraints, leading to first- or second-order differential-algebraic equations (DAEs), otherwise known as descriptor systems. Such large-scale systems generally lead to massive memory requirements and enormous computational complexity, thus restricting frequent simulations, which are required by many applications. To resolve these complexities, the higher-dimensional system may be approximated by a substantially lower-dimensional one through model order reduction (MOR) techniques. Computational Methods for Approximation of Large-Scale Dynamical Systems discusses computational techniques for the MOR of large-scale sparse LTI CT systems. Although the book puts emphasis on the MOR of descriptor systems, it begins by showing and comparing the various MOR techniques for standard systems. The book also discusses the low-rank alternating direction implicit (LR-ADI) iteration and the issues related to solving the Lyapunov equation of large-scale sparse LTI systems to compute the low-rank Gramian factors, which are important components for implementing the Gramian-based MOR. Although this book is primarily aimed at post-graduate students and researchers of the various SET disciplines, the basic contents of this book can be supplemental to the advanced bachelor's-level students as well. It can also serve as an invaluable reference to researchers working in academics and industries alike. Features: Provides an up-to-date, step-by-step guide for its readers. Each chapter develops theories and provides necessary algorithms, worked examples, numerical experiments and related exercises. With the combination of this book and its supplementary materials, the reader gains a sound understanding of the topic. The MATLAB® codes for some selected algorithms are provided in the book. The solutions to the exercise problems, experiment data sets and a digital copy of the software are provided on the book's website; The numerical experiments use real-world data sets obtained from industries and research institutes.

Frequency Weighted Model Order Reduction Techniques with Error Bounds

Model Order Reduction: Theory, Research Aspects and Applications

Frequency Weighted Model Order Reduction Techniques

Model Reduction of Complex Dynamical Systems

Mathematical models are used to simulate, and sometimes control, the behavior of physical and artificial processes such as the weather and very large-scale integration (VLSI) circuits. The increasing need for accuracy has led to the development of highly complex models. However, in the presence of limited computational accuracy and storage capabilities model reduction (system approximation) is often necessary. Approximation of Large-Scale Dynamical Systems provides a comprehensive picture of model reduction, combining system theory with numerical linear algebra and computational considerations. It addresses the issue of model reduction and the resulting trade-offs between accuracy and complexity. Special attention is given to numerical aspects, simulation questions, and practical applications.

The special volume offers a global guide to new concepts and approaches concerning the following topics: reduced basis methods, proper orthogonal decomposition, proper generalized decomposition, approximation theory related to model reduction, learning theory and compressed sensing, stochastic and high-dimensional problems, system-theoretic methods, nonlinear model reduction, reduction of coupled problems/multiphysics, optimization and optimal control, state estimation and control, reduced order models and domain decomposition methods, Krylov-subspace and interpolatory methods, and applications to real industrial and complex problems. The book represents the state of the art in the development of reduced order methods. It contains contributions from internationally respected experts, guaranteeing a wide range of expertise and topics. Further, it reflects an important effor t, carried out over the last 12 years, to build a growing research community in this field. Though not a textbook, some of the chapters can be used as reference materials or lecture notes for classes and tutorials (doctoral schools, master classes).

Covers the latest developments in modeling elastohydrodynamic lubrication (EHL) problems using the finite element method (FEM) This comprehensive guide introduces readers to a powerful technology being used today in the modeling of elastohydrodynamic lubrication (EHL) problems. It provides a general framework based on the finite element method (FEM) for dealing with multi-physical problems of complex nature (such as the EHL problem) and is accompanied by a website hosting a user-friendly FEM software for the treatment of EHL problems, based on the methodology described in the book. Finite Element Modeling of Elastohydrodynamic Lubrication Problems begins with an introduction to both the EHL and FEM fields. It then covers Standard FEM modeling of EHL problems, before going over more advanced techniques that employ model order reduction to allow significant savings in computational overhead. Finally, the book looks at applications that show how the developed modeling framework could be used to accurately predict the performance of EHL contacts in terms of lubricant film thickness, pressure build-up and friction coefficients under different configurations. Finite Element Modeling of Elastohydrodynamic Lubrication Problems offers in-depth chapter coverage of Elastohydrodynamic Lubrication and its FEM Modeling, under Isothermal Newtonian and Generalized-Newtonian conditions with the inclusion of Thermal Effects; Standard FEM Modeling; Advanced FEM Modeling, including Model Order Reduction techniques; and Applications, including Pressure, Film Thickness and Friction Predictions, and Coated EHL. This book: Comprehensively covers the latest technology in modeling EHL problems Focuses on the FEM modeling of EHL problems Incorporates advanced techniques based on model order reduction Covers applications of the method to complex EHL problems Accompanied by a website hosting a user-friendly FEM-based EHL software Finite Element Modeling of Elastohydrodynamic Lubrication Problems is an ideal book for researchers and graduate students in the field of Tribology.

Separated Representations and PGD-Based Model Reduction

Advanced Model-Order Reduction Techniques for Large Scale Dynamical Systems

Model Order Reduction Techniques for Circuits and Interconnects Simulation

Model Order Reduction for Efficient Modeling and Simulation of Interconnect Networks

Computational Methods for Approximation of Large-Scale Dynamical Systems