Model Order Reduction Techniques With Applications In Finite Element Analysis

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Model Order Reduction and Data-Driven Computational Modeling for Linear and Nonlinear Solids

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.

Model Order Reduction for Parametric Non-linear Mechanical Systems: State of the Art and Future Research

Comprehensive treatment of approximation methods for filters and controllers. It is fully up to date, and it is authored by two leading researchers who have personally contributed to the development of some of the methods. Balanced truncation, Hankel norm reduction, multiplicative reduction, weighted methods and coprime factorization methods are all discussed. The book is amply illustrated with examples, and will equip practising control engineers and graduates for intelligent use of commercial software modules for model and controller reduction.

Reduced Order Methods for Modeling and Computational Reduction

Dimension Reduction of Large-Scale Systems

The topic of Uncertainty Quantification (UQ) has witnessed massive developments in response to the promise of achieving risk mitigation through scientific prediction. It has led to the integration of ideas from mathematics, statistics and engineering being used to lend credence to predictive assessments of risk but also to design actions (by engineers, scientists and investors) that are consistent with risk aversion. The objective of this Handbook is to facilitate the dissemination of the forefront of UQ ideas to their audiences. We recognize that these audiences are varied, with interests ranging from theory to application, and from research to development and even execution.

Theory and Applications of Non-integer Order Systems

Physics-based numerical simulation remains challenging as the complexity of today's high-fidelity models has dramatically increased. Model order reduction (MOR) and data-driven modeling, based on the emerging techniques of data learning and physical modeling, present a promising way to tackle the computational bottleneck related to the computational intensity and model complexity. Nevertheless, MOR has proven to be significantly more difficult for parameterized mechanics systems that exhibit a wide variety of parameter-dependent nonlinear behaviors or that involve localized essential features.

The first objective of this work is to develop robust, physics-preserving MOR methods. As constructing a low-dimensional MOR model can be considered as the hybrid data-physics approach, one can optimize it through a learning process using both data and physical models. As such, we first propose a MOR method based on decomposed reduced-order projections that well preserve the essential near-tip characteristic for fracture mechanics. Moreover, we develop an enhanced reduced-order basis to construct a low-dimensional subspace, deriving from a generalized manifold learning framework that allows the employment of local information in the data structure during the learning phase. This approach can yield a robust reduced-order model against noise and outliers and is well suited for parameterized nonlinear physical systems. Finally, a nonlinear MOR for a meshfree Galerkin formulation with the stabilized conforming nodal integration (SCNI) scheme is developed to yield a pure node based MOR that is particularly effective for hyper-reduction techniques. A numerical example of two-phase hyperelastic solid with perturbed loading conditions is used to validate the effectiveness of the proposed reduction method. The second goal of the dissertation is to develop a robust data-driven computational framework, which provides an alternative to conventional scientific computing for complex materials. This framework aims at performing physical simulation by directly interacting with material data via machine learning procedures instead of employing phenomenological constitutive models, and especially addressing the robustness issue associated with noisy and scarce data. To this end, we propose to search data solutions from a locally reconstructed convex hull associated with the k-nearest neighbor points, which leads to robustness to noisy data and ensures convergence stability. The accuracy and robustness of the proposed data-driven approach are demonstrated in the modeling of linear and nonlinear elasticity problems. In addition, we present a preliminary result of data-driven modeling of biological tissue using material data collected from laboratory testing on heart valve tissue, showing the potential of data-driven simulation by integrating physical modeling and machine learning techniques.

Fractional-order Systems and Controls

Simulation based on mathematical models plays a major role in computer aided design of integrated circuits (ICs). Decreasing structure sizes, increasing packing densities and driving frequencies require the use of refined mathematical models, and to take into account secondary, parasitic effects. This leads to very high dimensional problems which nowadays require simulation times too large for the short time-to-market demands in industry. Modern Model Order Reduction (MOR) techniques present a way out of this dilemma in providing surrogate models which keep the main characteristics of the device while requiring a significantly lower simulation time than the full model. With Model Reduction for Circuit Simulation we survey the state of the art in the challenging research field of MOR for ICs, and also address its future research directions. Special emphasis is taken on aspects stemming from miniturisations to the nano scale. Contributions cover complexity reduction using e.g., balanced truncation, Krylov-techniques or POD approaches. For semiconductor applications a focus is on generalising current techniques to differential-algebraic equations, on including design parameters, on preserving stability, and on including nonlinearity by means of piecewise linearisations along solution trajectories (TPWL) and interpolation techniques for nonlinear parts. Furthermore the influence of interconnects and power grids on the physical properties of the device is considered, and also top-down system design approaches in which detailed block descriptions are combined with behavioral models. Further topics consider MOR and the combination of approaches from optimisation and statistics, and the inclusion of PDE models with emphasis on MOR for the resulting partial differential algebraic systems. The methods which currently are being developed have also relevance in other application areas such as mechanical multibody systems, and systems arising in chemistry and to biology. The current number of books in the area of MOR for ICs is very limited, so that this volume helps to fill a gap in providing the state of the art material, and to stimulate further research in this area of MOR. Model Reduction for Circuit Simulation also reflects and documents the vivid interaction between three active research projects in this area, namely the EU-Marie Curie Action ToK project O-MOORE-NICE (members in Belgium, The Netherlands and Germany), the EU-Marie Curie Action RTN-project COMSON (members in The Netherlands, Italy, Germany, and Romania), and the German federal project System reduction in nano-electronics (SyreNe).

Model Reduction and Approximation

This book examines the bottom-up applicability of swarm intelligence to solving multiple problems, such as curve fitting, image segmentation, and swarm robotics. It compares the capabilities of some of the better-known bio-inspired optimization approaches, especially Particle Swarm Optimization (PSO), Darwinian Particle Swarm Optimization (DPSO) and the recently proposed Fractional Order Darwinian Particle Swarm Optimization (FODPSO), and comprehensively discusses their advantages and disadvantages. Further, it demonstrates the superiority and key advantages of using the FODPSO algorithm, such as its ability to provide an improved convergence towards a solution, while avoiding sub-optimality. This book offers a valuable resource for researchers in the fields of robotics, sports science, pattern recognition and machine learning, as well as for students of electrical engineering and computer science.

Handbook of Uncertainty Quantification

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.

Finite Element Modeling of Elastohydrodynamic Lubrication Problems

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.

Reduced-Order Modeling (ROM) for Simulation and Optimization

Deriving a reasonable mathematical model is fundamental to the analysis, design and control of a dynamic system. The most important factor in model-reduction procedures is approximation error. Sometimes, this reduction error is more important over a certain frequency band than other frequencies, and taking account of this has led to the development of frequency weightings in the model-reduction procedure. This book will describe this technique and outline major applications. Topics covered include: an introduction to model reduction and frequency-weighted model reduction problems; mathematical methods used in various model reduction techniques; methods for linear systems; computational techniques; balanced realization based methods for both continuous and discrete systems; stability and passivity preserving techniques; single-sided and double-sided frequency-weighted reduction problems; frequency-weighted Hankel singular values and Enns techniques; limited frequency interval controllability and observability Gramians for continuous and discrete systems and model reduction approaches based on these Gramians; and practical application examples. This will be essential reading for researchers in system control, modelling and signal processing. It will also be of interest to graduates in the field.

Model Order Reduction: Theory, Research Aspects and Applications

rd This book constitutes a collection of extended versions of papers presented at the 23 IFIP TC7 Conference on System

Modeling and Optimization, which was held in C- cow, Poland, on July 23–27, 2007. It contains 7 plenary and 22 contributed articles, the latter selected via a peer reviewing process. Most of the papers are concerned with optimization and optimal control. Some of them deal with practical issues, e. g. , p- formance-based design for seismic risk reduction, or evolutionary optimization in structural engineering. Many contributions concern optimization of infini- dimensional systems, ranging from a general overview of the variational analysis, through optimization and sensitivity analysis of PDE systems, to optimal control of neutral systems. A significant group of papers is devoted to shape analysis and opti- zation. Sufficient optimality conditions for ODE problems, and stochastic control methods applied to mathematical finance, are also investigated. The remaining papers are on mathematical programming, modeling, and information technology. The conference was the 23rd event in the series of such meetings biennially org- ized under the auspices of the Seventh Technical Committee “Systems Modeling and Optimization” of the International Federation for Information Processing (IFIP TC7).

Model Order Reduction Techniques with Applications in Finite Element Analysis

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.

Frequency Weighted Model Order Reduction

This book provides an overview of the research done and results obtained during the last ten years in the fields of fractional systems control, fractional PI and PID control, robust and CRONE control, and fractional path planning and path tracking. Coverage features theoretical results, applications and exercises. The book will be useful for post-graduate students who are looking to learn more on fractional systems and control. In addition, it will also appeal to researchers from other fields interested in increasing their knowledge in this area.

Surveys in Differential-Algebraic Equations IV

This monograph explains the principles and applications of model reduction techniques, and the dynamic condensation technique in particular. It covers all the potentially useful condensation methods including static, exact, and iterative dynamic condensation and SEREP.

Interpolatory Methods for Model 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.

Model Order Reduction Methods for Data Assimilation

The Encyclopedia of Systems and Control collects a broad range of short expository articles that describe the current state of the art in the central topics of control and systems engineering as well as in many of the related fields in which control is an enabling technology. The editors have assembled the most comprehensive reference possible, and this has been greatly facilitated by the publisher’s commitment continuously to publish updates to the articles as they become available in the future. Although control engineering is now a mature discipline, it remains an area in which there is a great deal of research activity, and as new developments in both theory and applications become available, they will be included in the online version of the encyclopedia. A carefully chosen team of leading authorities in the field has written the well over 250 articles that comprise the work. The topics range from basic principles of feedback in servomechanisms to advanced topics such as the control of Boolean networks and evolutionary game theory. Because the content has been selected to reflect both foundational importance as well as subjects that are of current interest to the research and practitioner communities, a broad readership that includes students, application engineers, and research scientists will find material that is of interest.

System-level Modeling of MEMS

Reduced Basis Methods for Partial Differential Equations

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.

System Modeling and Optimization

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.

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

Reduced order models, or model reduction, have been used in many technologically advanced areas to ensure the associated complicated mathematical models remain computable. For instance, reduced order models are used to simulate weather forecast models and in the design of very large scale integrated circuits and networked dynamical systems. For linear systems, the model reduction problem has been addressed from several perspectives and a comprehensive theory exists. Although many results and efforts have been made, at present there is no complete theory of model reduction for nonlinear systems or, at least, not as complete as the theory developed for linear systems. This monograph presents, in a uniform and complete fashion, moment matching techniques for nonlinear systems. This includes extensive sections on nonlinear time-delay systems; moment matching from input/output data and the limitations of the characterization of moment based on a signal generator described by differential equations. Each section is enriched with examples and is concluded with extensive bibliographical notes. This monograph provides a comprehensive and accessible introduction into model reduction for researchers and students working on non-linear systems.

Machine Learning for Model Order Reduction

This monograph covers some selected problems of positive and fractional electrical circuits composed of resistors, coils, capacitors and voltage (current) sources. The book consists of 8 chapters, 4 appendices and a list of references. Chapter 1 is devoted to fractional standard and positive continuous-time and discrete-time linear systems without and with delays. In chapter 2 the standard and positive fractional electrical circuits are considered and the fractional electrical circuits in transient states are analyzed. Descriptor linear electrical circuits and their properties are investigated in chapter 3, while chapter 4 is devoted to the stability of fractional standard and positive linear electrical circuits. The reachability, observability and reconstructability of fractional positive electrical circuits and their decoupling zeros are analyzed in chapter 5. The fractional linear electrical circuits with feedbacks are considered in chapter 6. In chapter 7 solutions of minimum energy control for standard and fractional systems with and without bounded inputs is presented. In chapter 8 the fractional continuous-time 2D linear systems described by the Roesser type models are investigated.

Model Order Reduction Techniques with Applications in Finite Element Analysis

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.

Model Order Reduction Techniques for Circuits and Interconnects Simulation

This volume contains the proceedings of the IUTAM Symposium on Model Order Reduction of Coupled System, held in Stuttgart, Germany, May 22–25, 2018. For the understanding and development of complex technical systems, such as the human body or mechatronic systems, an integrated, multiphysics and multidisciplinary view is essential. Many problems can be solved within one physical domain. For the simulation and optimization of the combined system, the different domains are connected with each other. Very often, the combination is only possible by using reduced order models such that the large-scale dynamical system is approximated with a system of much smaller dimension where the most dominant features of the large-scale system are retained as much as possible. The field of model order reduction (MOR) is interdisciplinary. Researchers from Engineering, Mathematics and Computer Science identify, explore and compare the potentials, challenges and limitations of recent and new advances.

Computational Methods for Approximation of Large-Scale Dynamical Systems

This edited monograph collects research contributions and addresses the advancement of efficient numerical procedures in the area of model order reduction (MOR) for simulation, optimization and control. The topical scope includes, but is not limited to, new out-of-the-box algorithmic solutions for scientific computing, e.g. reduced basis methods for industrial problems and MOR approaches for electrochemical processes. The target audience comprises research experts and practitioners in the field of simulation, optimization and control, but the book may also be beneficial for graduate students alike.

Nonlinear Model Reduction by Moment Matching

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

Model Reduction for Control System Design

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.

McMindfulness

This book collects papers from the 8th Conference on Non-Integer Order Calculus and Its Applications that have been held on September 20-21, 2016 in Zakopane, Poland. The preceding two conferences were held in Szczecin, Poland in 2015, and in Opole, Poland, in 2014. This conference provides a platform for academic exchange on the theory and application of fractional calculus between domestic and international universities, research institutes, corporate experts and scholars. The Proceedings of the 8th Conference on Non-Integer Order Calculus and Its Applications 2016 brings together rigorously reviewed contributions from leading international experts. The included papers cover novel various important aspects of mathematical foundations of fractional calculus, modeling and control of fractional systems as well as controllability, detectability, observability and stability problems for this systems.

Model Reduction of Parametrized Systems

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.

Fractional Linear Systems and Electrical Circuits

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.

Fractional Order Darwinian Particle Swarm Optimization

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 many-query 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.

Index-aware Model Order Reduction Methods

Fractional-order Systems and Controls details the use of fractional calculus in the description and modeling of systems, and in a range of control design and practical applications. It is largely self-contained, covering the fundamentals of fractional calculus together with some analytical and numerical techniques and providing MATLAB® codes for the simulation of fractional-order control (FOC) systems. Many different FOC schemes are presented for control and dynamic systems problems. Practical material relating to a wide variety of applications is also provided. All the control schemes and applications are presented in the monograph with either system simulation results or real experimental results, or both. Fractional-order Systems and Controls provides readers with a basic understanding of FOC concepts and methods, so they can extend their use of FOC in other industrial system applications, thereby expanding their range of disciplines by exploiting this versatile new set of control techniques.

Progress in Industrial Mathematics at ECMI 2002

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 primarly 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.

Fractional Order Differentiation and Robust Control Design

Abstract: One research objective in the Priority Program 1897 "Calm, Smooth and Smart" of the German Research Foundation (DFG – SPP 1897) is the development of model order reduction techniques for parametric non-linear mechanical systems to enable efficient design, simulation, analysis, optimization and control of those. As a starting point for our research, this contribution provides an overview of the main challenges and well-established reduction techniques in this research area, at that stage, neglecting parameter dependencies. This includes simulation-based as well as simulation-free reduction bases generation and hyperreduction of the non-linear force terms. An extension of the Krylov directions in moment matching based on the concept of modal derivatives is also sketched. (© 2017 Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim).

Advanced Model Order Reduction Techniques in VLSI Design

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.

Approximation of Large-Scale Dynamical Systems

The present volume comprises survey articles on various fields of Differential-Algebraic Equations (DAEs) which have widespread applications in controlled dynamical systems, especially in mechanical and electrical engineering and a strong relation to (ordinary) differential equations. The individual chapters provide reviews, presentations of the current state of research and new concepts in - History of DAEs - DAE aspects of mechanical multibody systems - Model reduction of DAEs - Observability for DAEs - Numerical Analysis for DAEs The results are presented in an accessible style, making this book suitable not only for active researchers but also for graduate students (with a good knowledge of the basic principles of DAEs) for self-study.

Model Order Reduction

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.

IUTAM Symposium on Model Order Reduction of Coupled Systems, Stuttgart, Germany, May 22–25, 2018

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).

Model Order Reduction Techniques with Applications in Electrical Engineering

This volume contains the proceedings of the twelfth conference of the Euro pean Consortium for Mathematics in Industry. ECMI was founded in 1986 in to foster research and education in Mathematics in Industry in Europe order and these biannual conferences are the show case for ECMI's research. It is a pleasure to see that six of the plenary speakers have submitted papers for this volume. Their contributions illustrate the breadth of applica tions and the variety of mathematical and computational techniques that are embraced by ECMI. ECMI is also committed to the education of students and it is encouraging that a number of the papers are given by students. The Wacker Prize, which is offered for a Masters Level thesis on an industrial problem, always attracts excellent entries and this year's winner, Nicole Marheineke, is no exception. This is the first time that an ECMI conference has been held in Eastern Europe and the ECMI Council is very grateful to Professor Andris Buikis and his colleagues in Latvia and Lithuania for the excellent job they have done. Thanks too go to the European Union which supported 30 delegates at this conference via TMR Contract No ERBFMRXCT 97-0117 'Differential Equations in Industry and Commerce'. The final meeting of this network was held during this conference which provided a platform for network members to describe their work to a wider audience.

Encyclopedia of Systems and Control

A lively and razor-sharp critique of mindfulness as it has been enthusiastically co-opted by corporations, public schools, and the US military. Mindfulness is now all the rage. From celebrity endorsements to monks, neuroscientists and meditation coaches rubbing shoulders with CEOs at the World Economic Forum in Davos, it is clear that mindfulness has gone mainstream. Some have even called it a revolution. But what if, instead of changing the world, mindfulness has become a banal form of capitalist spirituality that mindlessly avoids social and political transformation, reinforcing the neoliberal status quo? In McMindfulness, Ronald Purser debunks the so-called "mindfulness revolution," exposing how corporations, schools, governments and the military have co-opted it as technique for social control and self-pacification. A lively and razor-sharp critique, Purser busts the myths its salesmen rely on, challenging the narrative that stress is self-imposed and mindfulness is the cure-all. If we are to harness the truly revolutionary potential of mindfulness, we have to cast off its neoliberal shackles, liberating mindfulness for a collective awakening.

Model Reduction for Circuit Simulation

System-level modeling of MEMS - microelectromechanical systems - comprises integrated approaches to simulate, understand, and optimize the performance of sensors, actuators, and microsystems, taking into account the intricacies of the interplay between mechanical and electrical properties, circuitry, packaging, and design considerations. Thereby, system-level modeling overcomes the limitations inherent to methods that focus only on one of these aspects and do not incorporate their mutual dependencies. The book addresses the two most important approaches of system-level modeling, namely physics-based modeling with lumped elements and mathematical modeling employing model order reduction methods, with an emphasis on combining single device models to entire systems. At a clearly understandable and sufficiently detailed level the readers are made familiar with the physical and mathematical underpinnings of MEMS modeling. This enables them to choose the adequate methods for the respective application needs. This work is an invaluable resource for all materials scientists, electrical engineers, scientists working in the semiconductor and/or sensor industry, physicists, and physical chemists.