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Model and Data Reduction for Control, Identification and Compressed Sensing

Boris Krämer

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in partial fulfillment of the requirements for the degree of

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in
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John A.Burns, Chair
Jeffrey T. Borggaard
Eugene Cliff
Serkan Gugercin
Lizette Zietsman

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Model and Data Reduction for Control, Identification and Compressed Sensing

Boris Krämer

(ABSTRACT)

This dissertation focuses on problems in design, optimization and control of complex, large-scale dynamical systems from different viewpoints. The goal is to develop new algorithms and methods, that solve real problems more efficiently, together with providing mathematical insight into the success of those methods. There are three main contributions in this dissertation.

In Chapter 3, we provide a new method to solve large-scale algebraic Riccati equations, which arise in optimal control, filtering and model reduction. We present a projection based algorithm utilizing proper orthogonal decomposition, which is demonstrated to produce highly accurate solutions at low rank. The method is parallelizable, easy to implement for practitioners, and is a first step towards a matrix free approach to solve AREs. Numerical examples for $n \geq 10^6$ unknowns are presented.

In Chapter 4, we develop a system identification method which is motivated by tangential interpolation. This addresses the challenge of fitting linear time invariant systems to input-output responses of complex dynamics, where the number of inputs and outputs is relatively large. The method reduces the computational burden imposed by a full singular value decomposition, by carefully choosing directions on which to project the impulse response prior to assembly of the Hankel matrix. The identification and model reduction step follows from the eigensystem realization algorithm. We present three numerical examples, a mass spring damper system, a heat transfer problem, and a fluid dynamics system. We obtain error bounds and stability results for this method.

Chapter 5 deals with control and observation design for parameter dependent dynamical systems. We address this by using local parametric reduced order models, which can be used online. Data available from simulations of the system at various configurations (parameters, boundary conditions) is used to extract a sparse basis to represent the dynamics (via dynamic mode decomposition). Subsequently, a new, compressed sensing based classification algorithm is developed which incorporates the extracted dynamic information into the sensing basis. We show that this augmented classification basis makes the method more robust to noise, and results in superior identification of the correct parameter. Numerical examples consist of a Navier-Stokes, as well as a Boussinesq flow application.