National Institute of Technology Rourkela

Synopsis Seminar

Seminar Title	: Model Order Reduction Methods: Improvements and Applications
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Abstract

: Ordinary or partial differential equations of large dimensions describe the system dynamics following theoretical considerations and physical principles. However, due to their large dimensions, real-time simulations, and parameter identification, creating controls may be computationally and practically inconvenient. It is practical and occasionally required to look for similar but simplified-order equations that accurately represent a high-order system's input-output behavior and dominant aspects. In control and system theory, the time and frequency domains have seen various model order reduction (MOR) strategies presented by multiple researchers. Every order simplification method has advantages and disadvantages, and works well under certain circumstances. The traditional techniques, e.g., Pade approximation, time moment marching, and Krylov subspace, have instability issues, stability equations, Routh approximation, dominant pole retention, and pole clustering methods have the characteristic of approximating poles near the origin, and the balanced truncation method (BTM) has a steady-state issue. It is observed that metaheuristic search-based MOR methods utilize a random selection of the search space to obtain the reduced order model (ROM), increasing the algorithm's complexity and simulation time.

To address these issues, this thesis strives to provide MOR approaches for large-scale LTI integer order systems, fractional order systems, and integer order interval systems. The proposed traditional and metaheuristic search-based MOR approaches are compared with recently proposed MOR techniques. This thesis offers a unique way of incorporating evolutionary algorithms into MOR applications using the interim ROM concept to select a compact search space. As a result, the proposed techniques circumvent evolutionary algorithms' significant issues: the random choice of the solution field and the lengthy simulations. The suggested solutions are on par with established MOR techniques regarding quality. Some of the proposed methods are applied to the design of PID controllers and compensators.

Chapter 3 proposes MOR approaches for large-scale LTI integer order systems. The first proposed approach utilizes the dominant pole selection-based generalized pole clustering technique the second approach uses the dominant pole selection-based logarithmic pole clustering technique the third approach utilizes model dominance index-based dominant pole selection the fourth approach uses the BTM the fifth method uses the balanced residualization method (BRM) to obtain the ROM denominator. A simple mathematical algorithm obtains the ROM numerator by matching time moments (TiMs) and Markov parameters (MaPs) in all the proposed methods. The sixth proposed approach uses the BTM, and the seventh uses the BRM to compute the ROM denominator polynomial. In contrast, the particle swarm optimization (PSO) algorithm calculates the numerator coefficients by minimizing specific performance attributes.

Almost every system has some degree of parameter uncertainty in the real world. Such numerical representations of uncertainty are referred to as interval systems. The computational complexity of MOR approaches grows when they adhere to interval arithmetic. Chapter 4 proposes two novel techniques to simplify the continuous-time interval systems. The first approach combines the dominant pole with the moment-matching algorithm based on the Kharitonov theorem. The second approach uses the BRM to obtain the ROM denominator, and a simple mathematical procedure obtains the numerator coefficients. The main advantage of the proposed approach is that the reduction algorithm deals with a linear system model instead of an interval model with interval arithmetic rules. Chapter 5 proposes three novel techniques to simplify the continuous time-fractional order systems. First, a modified BTM second, a composite method using the advantages of BRM and moment matching is proposed for MOR of commensurate and incommensurate order fractional systems. Most controller design approaches, in general, depend on choosing dominant poles that satisfy the closed-loop system performance. In this thesis, we considered a second-order closed-loop reference transfer function formulated based on the desired performance requirements. Several numerical examples from the literature are considered, and the results are compared with the state-of-the-art MOR techniques to determine the effectiveness of the proposed schemes. The MATLAB computer program has been used for all the numerical calculations.