National Institute of Technology Rourkela

Defence Seminar

Seminar Title	: Model Order Reduction Methods: Improvements and Applications
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Venue	: EE401
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Abstract : Large-dimensional ordinary or partial differential equations explain the system's dynamics, making stability analysis, modeling, and control design computationally challenging. The traditional model order reduction (MOR) techniques, in time and frequency domains, struggle with instability, approximating poles near the imaginary axis, steady-state gain error, low high-frequency response approximation, and computational intricacy for LTI integer order systems (IOSs), interval systems with parameter uncertainty, and fractional order systems (FOSs). The metaheuristic search-based MOR methods are criticised for random search space selection, optimizing more parameters, and increased complexity and simulation time. This thesis proposes various composite MOR approaches that integrate enhanced pole clustering, moment matching, balanced realization, and metaheuristic algorithms to address these issues.

Two enhanced pole clustering-based MOR approaches are proposed in the frequency domain for large-scale LTI fixed coefficient IOSs to preserve stability, actual dominant dynamics, and improved accuracy. The model dominance index (MDI) determines the pole dominance. The first proposed approach utilizes the MDI-assisted DPR-based generalized pole clustering technique (GPCT) to determine the ROM denominator and numerator by matching time moments (TiMs) and Markov parameters (MaPs). The second approach uses the MDI-assisted DPR-based improved logarithmic pole clustering technique to determine the ROM denominator and numerator by matching TiMs and MaPs.

Four enhanced balanced realization-based MOR approaches are proposed in the time domain for large-scale LTI fixed coefficient single-input single-output (SISO) and multipleinput output (MIMO) IOSs to address the steady-state gain issue and poor high-frequency approximation. The first two proposed approaches utilize the balanced truncation (BTM) and balanced residualization (BRM) to determine the ROM denominator parameters to ensure stability. The numerator parameters are determined by matching TiMs and MaPs to ensure steady-state and transient response matching. Later, the BTM and BRM approaches were extended by integrating with particle swarm optimization (PSO) to obtain the optimal numerator parameters by minimizing the integral square error (ISE) between the model and system. This procedure determines the PSO algorithm's initial parameter values and the
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search space's lower and upper bounds, using a strategic constant around the ROM numerator coefficients of BTM and BRM.

A strategy for MOR of interval systems is proposed by integrating the Kharitonov theorem, DPR, and matching the TiMs and MaPs. The Kharitonov theorem decomposes the interval dynamics into fixed transfer functions. 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, which enhances the computational efficiency while maintaining robustness. Finally, two novel techniques are proposed to simplify the continuous-time FOSs. The FOSs are transformed into analogous integer order versions using mathematical substitution and the Oustaloup approximation. Later, the BTM with steady state gain (SSG) preservation and BRM with matching TiMs and MaPs are used to obtain the ROMs. Finally, inverse substitution is performed to attain the fractional order form.

Several numerical SISO and MIMO examples from the literature, like power systems, Cuk converter, SMIB, interconnected systems, with uncertain and nonlinear behavior through interval and fractional order systems, are considered to validate the efficacy, precision, stability retention, and computational efficiency of the proposed algorithms subject to the state-of-the-art MOR techniques. The MATLAB computer program has been used for all the numerical calculations.