Automatic Generation of Minimal and Reduced Models for Structured Parametric Dynamical Systems

Igor Pontes Duff, Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg, Germany

Reduced-order modeling of large-scale complex dynamical systems is a necessary step for faster simulation, optimization, control, and uncertainty quantification studies. Model-order reduction (MOR) is a prevalent technique, allowing us to determine a reduced-order model (ROM). Developing efficient and robust MOR techniques has been an active research area in the last couple of decades within the fields of computational sciences and engineering.
In many instances, a system presents particular dynamical structures, such as time delays and/or higher-/fractional-order derivatives, and it is desirable to preserve such structures in the ROM. Moreover, these systems can have parameter dependencies that also need to be preserved. Therefore, the development of suitable tools for structure-preserving parametric MOR is crucial.

In this talk, we discuss a novel MOR framework for structured parametric dynamical systems, called dominant reachable and observable subspace-based projection (DROP). To that end, we first establish a connection between an interpolation-based MOR method with the reachable and observable subspaces of linear structured parametric systems. We show that if enough interpolation points are taken, then projection matrices of interpolation-based MOR encode these subspaces. As a consequence, we propose an approach to construct reduced-order systems preserving the common subspaces containing the most reachable as well as the most observable states. This approach can be seen as a combination of the interpolation-based method and some inspiration from the Loewner framework for first-order systems. Hence, we obtain a minimal-order surrogate model, capturing the dynamics of high-dimensional models with very high accuracy. Furthermore, we pay particular attention to the computational aspects of the proposed approach. We discuss how low-rank solutions of matrix equations can be utilized to speed-up the DROP method in a large-scale setting. Lastly, we illustrate the efficiency of the proposed methods by means of several examples, arising in science and engineering, and show a comparison with existing approaches.