University of Stuttgart

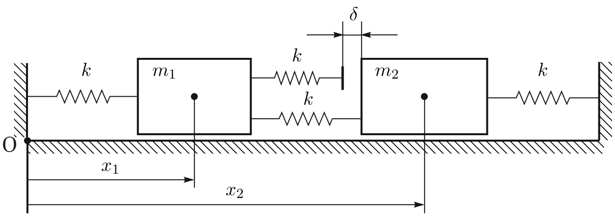
Institute for Nonlinear Mechanics

Master's thesis

Model Order Reduction of Piecewise Linear Soft-Stiff Mechanical Systems

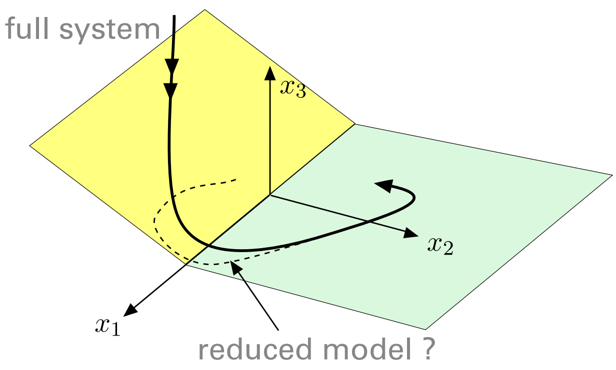
Topic Areas:	Model Order Reduction, Simulation Piecewise Linear Dynamical Systems
Advisors:	Yassine Karoui karoui@inm.uni-stuttgart.de
Responsible Professor:	Prof. Remco I. Leine
Prerequisites/Prior Knowledge:	Nonlinear Dynamics, Matlab

Computer simulations are routinely performed in today's technological world for modeling and response prediction of almost any physical phenomenon. Despite the tremendous increase in computational power over the past decades, the time required to solve high-dimensional discretized models remains a bottleneck towards efficient and optimal design of structures. Model order reduction (MOR) aims to reduce these computational efforts by introducing lower dimensional reduced systems which capture the main features of the original system. An additional computational challenge consists in the interplay between soft and stiff components yielding mechanical systems with a wide gap in the spectrum of natural frequencies, which is a common feature in engineering applications. This spectral gap introduces a small parameter responsible for a time scale separation in the global dynamics. Based on this slow-fast decomposition, the theory of singular perturbations serves as an exact nonlinear model reduction approach for smooth dynamical systems.



Example of a simple 2-DOF PWL mechanical oscillator.

However, real world mechanical systems include effects such as clearance and dry friction, which yield piecewise linear (PWL) dynamical systems.
In this master thesis project, you will aim to extend the reduction approach proposed in [1] to multiple degree of freedom PWL mechanical systems. To start this quest, you will learn the theoretical principles of the theory of singular perturbations. Then, you will apply the reduction approach on 2-DOF PWL mechanical oscillators with varying clearance gaps and implement the reduced order models (ROMs) in Matlab. This serves as a bridge towards the investigation of higher dimensional systems. Once the reduction procedure is well-understood, you will be encouraged to compare the results with other available reduction methods with a special focus on the undamped case and eventually consider piecewise nonlinear systems.



The full system trajectories are attracted to a lower dimensional manifold in the phase space and synchronize with the reduced model trajectories.

[1] A. Y. Karoui and R. I. Leine, *Model reduction of a periodically forced slow-fast continuous piecewise linear system*, Nonlinear Dynamics, 2023, [Manuscript submitted for publication].