Stable Model Reduction:  
A Projection Approach for NONLINEAR Systems in the 
More General Descriptor Form  
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The ability to generate accurate reduced-order models (ROMs) of nonlinear dynamical systems, such as analog circuits and micro-electro-mechanical systems (MEMS), is a crucial first step in the automatic design and optimization of such systems. One popular approach to model order reduction (MOR) of highly nonlinear systems employs trajectory-based methods, such as the piecewise-linear (PWL) approach. Despite substantial recent interest in such methods [1], [2], trajectory-based models (TBMs) have failed to gain widespread acceptance due to a lack of theoretical statements concerning the accuracy of the resulting ROMs. In this work we address one such theoretical issue: guaranteed stability. Specifically, we present a scheme for preserving stability in PWL models, whose system matrices possess a certain structure. We also propose a projection scheme that allows us to extend some of these stability results to PWL systems composed of arbitrary unstructured matrices.

The stability of nonlinear systems can be certified for instance by the existence of a Lyapunov function. Our stabilizing scheme ensures stability by constructing the projection matrices such that there exists a Lyapunov function for the resulting ROM. In the case where all the Jacobians of the linearized systems possess a certain structure, examples of which are given in [3], we present a projection routine that guarantees the existence of a quadratic Lyapunov function for both the large PWL model and the ROM. In the case where the system’s Jacobians have no structure and it is not known whether a Lyapunov function exists for the large PWL model, we utilize a new nonlinear projection to create a collection of stable reduced local models. The resulting nonlinear model is guaranteed to be at least locally stable. One example of a system that produces unstructured Jacobians, and thus potentially unstable TBMs, is a MEMS switch (shown in Figure 1). Figure 2 shows a sample output from the MEMS switch, a stable TBM generated by our approach, and an unstable TBM generated by the traditional approach. For further details on the stabilizing procedure, see [3].

REFERENCES