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Subspace and maximum likelihood identification of nonlinear mechanical systems

J.P. Noël [1], J. Schoukens [2] and G. Kerschen [1]

[1] Space Structures and Systems Laboratory
Aerospace and Mechanical Engineering Department
University of Liège
Chemin des chevreuils 1, B-4000, Liège, Belgium

[2] Department ELEC
Vrije Universiteit Brussel
Pleinlaan 2, B-1050, Brussels, Belgium

Abstract

The present work focuses on a recent nonlinear generalisation of the existing (linear) frequency-domain, discrete-time subspace methods applicable to mechanical systems. The proposed estimator, termed FNSI method, is interesting because it benefits from the numerical robustness and efficacy of subspace algorithms, while maintaining an acceptable computational burden. However, it derives estimates of the model parameters, namely the modal properties of the underlying linear system and the coefficients of the nonlinearities, based on deterministic arguments and one has thus no guarantee that the estimates still behave well in the presence of disturbing noise.

A possible alternative is to embed the identification problem in a stochastic framework through the minimisation of a well-chosen cost function incorporating noise information. In particular, the maximum likelihood cost function is attractive because it yields estimates of the model parameters with optimal stochastic properties, and simplifies to a weighted least-squares expression in the frequency domain. However, the maximum likelihood suffers from issues typically encountered in optimisation problems, especially related to initialisation.

The contribution of this work lies in the utilisation of the model parameter estimates provided by the FNSI method to serve as starting values for the minimisation of the maximum likelihood cost function. This initialisation strategy possesses the important advantage that the FNSI method generates a fully nonlinear model of the system under test, while classical approaches commonly use a linear model of the nonlinear system as starting point. This ensures that the resulting maximum likelihood model performs at least as good as the nonlinear subspace model. The complete methodology is demonstrated using experimental data measured on the Silverbox benchmark, an electronic circuit emulating the behaviour of a mechanical system with cubic nonlinearity.