An investigation into model extrapolation and stability in nonlinear system identification

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Abstract. The process of estimating a nonlinear model from experimental measurements of vibrating structures remains a challenging topic, despite the huge progress of recent years. One of the major issues is that the dynamical behaviour of a nonlinear system dramatically depends on the magnitude of the displacement response. Thus, the validity of an identified model structure is generally limited to a certain range of motion. Outside this range the stability of the solutions predicted by the model may not be guaranteed either. This work analyses the extrapolation capabilities of data-driven nonlinear state-space models based a subspace approach. An experimental magnetic beam with a strong geometric nonlinearity is driven through several levels of excitation using broadband random noise. The limitations of the estimated nonlinear state-space models are explored for strong nonlinear behaviour. Model predictions and measurements are compared to assess the accuracy of the identification results.

Introduction

Nonlinear system identification is an essential tool for modelling the dynamics of nonlinear structures, though it represents a challenging task especially for complex nonlinear phenomena [1]. The identification process generally involves three steps: nonlinear detection, characterization, and estimation. The first two steps can be addressed using ad-hoc methods or prior knowledge of the system. The last step involves the estimation of the model parameters from the experimental data, and it is strictly related to the range of motion covered by the data itself. This consideration arises from the fact that the dynamical behaviour of nonlinear systems significantly depends on the motion regimes. Therefore, even in the case of a successful estimation of a model structure, its validity is generally limited to a certain range of motion. This topic is explored in this work by investigating the extrapolation of data-driven nonlinear state-space models estimated using a subspace approach [2,3]. To this end, a magnetic beam with a nonlinear behaviour is driven with several levels of random excitation, and the limitations of the identification process are evaluated by comparing model predictions and measurements. The estimated models are also used to generate the system response under (simulated) harmonic excitation with different amplitudes, to assess the stability of the predicted solutions.

Results and discussions

Eight excitation levels have been considered, covering weak to strong nonlinear phenomena. A nonlinear state-space model was identified for each test level and the models were then used for a dual test: (*i*) the extrapolation towards stronger nonlinear behaviour and (*ii*) the stability of the predicted solutions. As an example, Figure 1 shows the measured data from 2 levels (level-2 and level-5) and the corresponding estimated nonlinear restoring force. The extrapolation generates in this case an unstable solution.

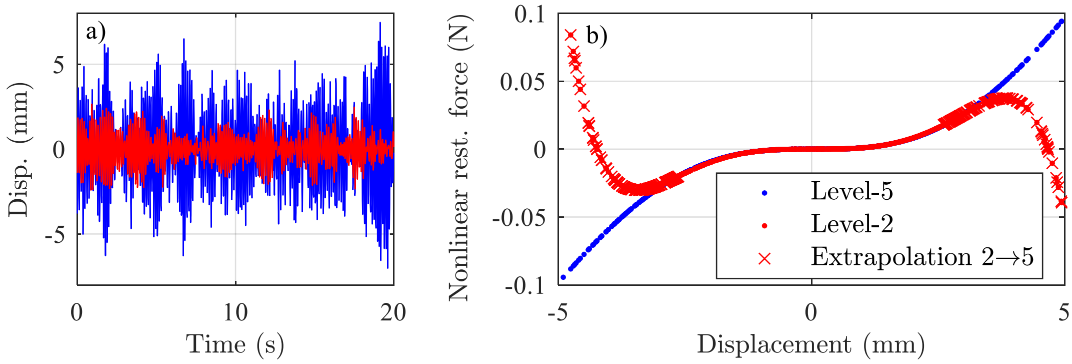

Figure 1: a) Measured data from level-2 (red) and level-5 (blue). b) Estimated nonlinear restoring force.

References

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