Nonlinear system identification of a multi-story building with geometrical nonlinearity using a deterministic output-only-data approach

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Abstract. Nonlinear system identification based on output-only data is challenging since the stochastic approaches require the structure to be excited by random input with a uniform Gaussian distribution. This paper applies a deterministic output-only approach to parameter estimation of a linear multi-story specimen with an amplitude-dependent geometrical nonlinearity. The approach is independent of the input type, value, and number but requires the excitation to be applied away from the nonlinearity. The vibration responses to high-amplitude excitations are taken into a subspace-based identification algorithm that simultaneously yields both nonlinear and underlying linear parameters. The process is verified by comparing the underlying linear parameters with the linear modal parameters of the structure under low-amplitude excitation. The results indicate a superior accuracy of the estimated parameters in the simulation and an acceptable confidence range for the experimental test.

Introduction

The nonlinear system identification is generally an input-output data-driven process since the input (load) and output (response) of nonlinear systems are not proportional. However, there are many real-world nonlinear structures excited by unmeasurable environmental or operational loads. Most recently two multi-test output-only approaches for nonlinear subspace system identification have been introduced based on a mass-change scheme [1] and an input location-change scheme [2]. In this paper, the deterministic subspace identification algorithm recently used for the multi-degree of freedom (MDOF) system [2], [3], is applied to an experimental multi-story building with geometrical nonlinearity (Fig. 1 -a). It was demonstrated when an MDOF is excited, the linear and nonlinear elements attached to DOFs away from the external force can be identified at a time using the response of the whole DOFs. The objective of the present study is to extend the applicability range of the approach to experimental identification of structures with amplitude-dependent nonlinearity type based on vibration response only. Compared to the recent works, the present one is dedicated to simplifying the implementation of the algorithm for the users through the available system identification toolbox in MATLAB and using real vibration measurements.

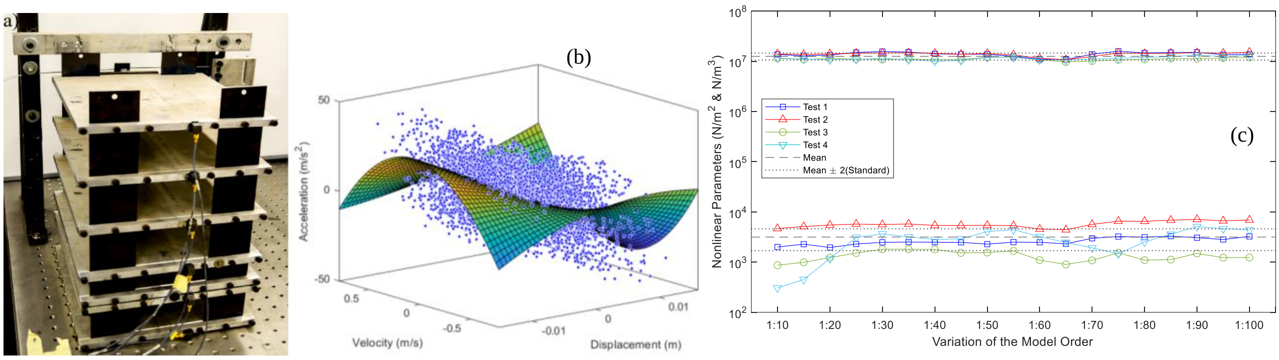

Figure 1: a) Multi-story building test setup with geometrical nonlinearity, b) nonlinear detection, c) nonlinear parameter estimation

Results and discussion

Figure 1-b displays the state-space phase plot of the fifth floor in a typical nonlinear test and corresponding fitted surface indicating the cubic stiffness behavior. Hence polynomial type basis function is used to characterize and estimate the nonlinear dynamics of the specimen. Figure 1-c demonstrates the variation of the nonlinear stiffness parameters estimated in different nonlinear tests. Despite a bias in the natural frequency and damping ratio estimates due to the process error for both integration operation and including the dynamical matrix components of the excited floor in each test, the mode shapes properly match. On the other hand, the stability of the estimated nonlinear parameters verifies the capability of the implemented identification algorithm using output-only measurements.

References

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