Université de Liège

Aerospace and Mechanical Engineering Department
Space Structures and Systems Laboratory

A Frequency-domain Approach to Subspace Identification of Nonlinear Systems

Application to Aerospace Structures

Thesis submitted in fulfilment of the requirements for the degree of
Doctor in Engineering Sciences

by

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February 2014

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Abstract

The construction of mathematical models from experimental data is an essential step in the design process of engineering systems. The different tasks involved in this activity, from the measurement and processing of data to the validation of the model, fall into the general field of system identification. In structural dynamics, the theoretical and experimental aspects of linear system identification have been successfully addressed since the early seventies, and mature analytical, computational and testing tools have emerged. Nonlinear system identification of vibrating structures has also enjoyed significant advances during the past few years. However, the common practice in industry is to ignore nonlinearities, arguably because their analysis is still regarded as impractical.

The objective of this doctoral thesis is precisely to progress towards the development of a practical system identification methodology dedicated to real-life nonlinear structures. The first facet of the thesis is to introduce a nonlinear generalisation in the frequency domain of the so-called subspace identification methods. The proposed frequency-domain nonlinear subspace identification (FNSI) approach yields accurate models of large-scale systems comprising strong nonlinearities, closely-spaced modes and high damping. Because it can also estimate a large number of parameters while maintaining an acceptable computational burden, the second facet of this research is to investigate the utilisation of cubic splines as a very flexible means to model complex nonlinearities. Finally, the third facet of the present work is to derive nonlinear models with optimal statistical properties in the presence of measurement noise. This is achieved by embedding the FNSI method into the maximum likelihood identification framework.

The scope of the identification and modelling tools developed in this thesis encompasses nonlinear structural systems originating from the various areas of vibration engineering, including the aerospace, mechanical or civil fields, amongst others. Throughout the dissertation, these tools are illustrated using numerical and experimental structures of increasing complexity, mainly related to aerospace applications.