7^{th} *International Conference on Nonlinear Vibrations, Localization and Energy Transfer*
July 1-4, 2019 - Marseille, France

Nonlinear System Identification: Current Status and Challenges Ahead

G. Kerschen, J.P. Noël

University of Liège
Aerospace and Mechanical Engineering Department
Liège, Belgium
g.kerschen@ulg.ac.be

Abstract Even if we are entering the age of virtual prototyping, *experimental testing* and *system identification* still play a key role because they help the structural dynamicist reconcile numerical predictions with experimental investigations. The past decade witnessed a shift in emphasis in nonlinear system identification, accommodating the growing industrial need for a first generation of tools capable of addressing complex nonlinearities in larger-scale structures. The objective of this presentation is to survey some of the key developments which arose in the field and to present the remaining challenges.

System identification refers herein to the development (or the improvement) of mathematical models from input and output measurements performed on the real structure using vibration sensing devices [1]. This presentation, which is based on the two review papers [2, 3], provides first a brief historical perspective of the progress of nonlinear system identification starting from the seminal work of Masri and Caughey [4].

After this historical perspective, it is shown that the identification process may be regarded as a progression through three steps, namely detection, characterization and parameter estimation, as outlined in Figure 1. Once nonlinear behavior has been detected, a nonlinear system is said to be characterized after the location, type and functional form of all nonlinearities throughout the system are determined. The parameters of the selected model are then estimated using linear least-squares fitting or nonlinear optimization algorithms depending upon the method considered.

1. Detection: *Is there?* Ascertain if nonlinearity exists in the structural behaviour, *e.g.*, yes.

2. Characterization: *Where? What? How?*

   (a) Locate the nonlinearity, *e.g.*, at the joint;

   (b) determine the type of nonlinearity, *e.g.*, Coulomb friction;

   (c) select the functional form of the nonlinearity, *e.g.*, $g(q, \dot{q}) = c\,\mathrm{sign}(\dot{q})$.

3. Parameter estimation: *How much?*

   Calculate the coefficients of the nonlinearity model and quantify their uncertainty, *e.g.*, in a probabilistic sense, $c \sim \mathcal{N}(5.47, 1)$.

Figure 1: Identification process for nonlinear structural models.

Figure 2: Decommissionned F-16 aircraft at Saffraanberg Airforce Base.

The three steps are illustrated using a real-life aerospace structure, i.e., the F-16 aircraft in Figure 2, for which a detailed measurement campaign was carried out in 2014 in collaboration with Siemens Industry Software [5]. It is shown that the F-16 possesses very interesting nonlinear dynamics, including complex nonlinear stiffness and damping between the wing and the payload.

The presentation concludes by discussing future research directions. Specific attention is paid to experimental continuation techniques, the physical realization of numerical continuation. It exploits feedback control strategies to stabilize the measured response, enabling both stable and unstable branches to be measured.

References

[1] K. Worden and G. Tomlinson, *Nonlinearity in Structural Dynamics: Detection, Identification and Modelling*, Institute of Physics Publishing, Bristol and Philadelphia, 2001.

[2] G. Kerschen, K. Worden, A.F. Vakakis and J.C. Golinval, *Past, present and future of nonlinear system identification in structural dynamics*, Mechanical Systems and Signal Processing 20, 505-592, 2006.

[3] J.P. Noel, G. Kerschen, *Nonlinear system identification in structural dynamics: 10 more years of progress*, Mechanical Systems and Signal Processing 83, 2-35, 2017.

[4] S.F. Masri and T.K. Caughey, *A nonparametric identification technique for nonlinear dynamic problems*, Journal of Applied Mechanics 46, 443-447, 1979.

[5] T. Dossogne, J.P. Noel, C. Grappasonni, G. Kerschen, B. Peeters et al., Nonlinear ground vibration identification of an F-16 aircraft - Part II: understanding nonlinear behaviour in aerospace structures using sine-sweep testing, Proceedings of the IFASD conference, Saint Petersburg, Russia, 2015.