
Parameter identification of nonlinear dynamical systems through the Hilbert Huang Transform and the Multiple Scales Method

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Abstract

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The parameter identification of mechanical systems is an open issue, which has been largely addressed in the literature over the years. As great emphasis has been given to linear systems, literature applications on nonlinear problems are more recent (1). However, as nonlinearities can exhibit a predominant role in the response of dynamical systems, identification of the parameters ruling their contribution appears as a challenge in the field of inverse problems.

The idea behind this work takes its inspiration from (2), where a 2-d.o.f nonlinear mechanical system was considered and its parameters identified combining the Hilbert Huang Transform (HHT) with the Complexification Averaging (CX-A) (3).

Here the same problem has been tackled but combining HHT with Multiple Scales Method (MSM) (4). The procedure based on the combination of MSM and HHT is here roughly described: 1) System response time series are acquired after application of nonzero initial conditions (they are either taken from experimental tests or from numerical simulations); 2) the HHT is applied to the time series, performing the Empirical Mode Decomposition (EMD) to decompose the original signal in Intrinsic Mode Functions (IMF), i.e. mono-component functions in terms of frequency; 3) the inverse problem is therefore generated by using the Amplitude Modulation Equations (AME) evaluated by the MSM; 4) pseudo-inversion of the AME provides the identified system parameters.

It is found that the proposed method can suitably identify the system parameters for different case studies, ranging from 1-dof systems to continuous ones. As a benchmark, parameter identification through the SINDy algorithm (5) is carried out and comparisons with the proposed technique addressed.

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References

- (1) Worden, K., Tomlinson, G.R., *Nonlinearity in Structural Dynamics: Detection, Identification and Modelling*, Institute of Physics Publishing, Bristol, UK, (2001).
- (2) Kerschen, G., Vakakis, A.F., Lee, Y.S., Mc Farland, D.M., Bergman, L.A., "Toward a Fundamental Understanding of the Hilbert-Huang Transform in Nonlinear Structural Dynamics", *Journal of Vibration and Control*, 14(1-2), pages 77-105 (2008).
- (3) Manevitch, L., "The Description of Localized Normal Modes in a Chain of Nonlinear Coupled Oscillators Using Complex Variables", *Nonlinear Dynamics*, 25 95-109 (2001).
- (4) Nayfeh, A.H., Mook, D.T, *Nonlinear Oscillations*, John Wiley & Sons, New York, (1995).
- (5) Brunton, S.L., Proctor, J.L., Kutz, J. N., "Discovering governing equations from data by sparse identification of nonlinear dynamical systems" in *Proceedings of the National Academy of Sciences*, 113(15), pages 3932-3937 (2016).