Enhanced Modal Identification for Long-term Integrity Assessment (EMILIA). A Time-Dependent Dynamic Identification Algorithm for Structural Health Monitoring

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ABSTRACT

Conducting dynamic testing under operational conditions for Structural Health Monitoring intents (SHM) is imperative for appropriate maintenance and preservation of existing modern structures and heritage buildings [1,2,3]. Traditional structural dynamic identification methods used in Operational Modal Analysis (OMA) can accurately estimate parameters like modal frequencies, damping ratios and mode shapes [4,5,6], but some of these methods present problems related to the difficulties in identifying close-spaced modes or uncertainties when working with noise-contaminated measurements [7,8,9,10]. On the other hand, most methods based on output-only data work with parametric eigenvalue decompositions of a weighted data matrix, like the Singular Value Decomposition (SVD) of the Power Spectral Density matrix (PSD) in Frequency Domain Decomposition methods (FDD) [11,12,13], or the SVD of Hankel matrixes in Stochastic System Identification methods (SSI) [14,15,16]. Thus, they are restricted to the linear-elastic range (no-damage, no-yielding) and are incapable of performing dynamic identification in the presence of nonlinearities. Moreover, these methods cannot generate results as time-dependent functions, as they are limited to the comparative assessment between different structural conditions (e.g. before and after a particular event), thereby being unable to provide any information about the actual temporal evolution of dynamic parameters like natural frequencies and mode shapes. For the development of innovative dynamic identification methods for SHM, performing dynamic identification in the presence of nonlinearities and the capability of computing time-dependent parameters are essential tasks to accomplish [17,18,19,20].

This paper describes the design, test and validation processes of a dynamic identification algorithm aimed at the time-dependent assessment of both modern structures and heritage buildings for seismic engineering purposes. Time-varying dynamic parameters that can be computed are modal frequencies, modal displacement, modal curvatures, and higher derivatives of mode shapes. Making use of output-only vibration measurements, the non-parametric algorithm can generate dynamic features results as time-dependent functions for the complete observation period. The algorithm can work in the presence of different dynamic loads and non-linear structural behaviour, close spectral frequency components and highly noise-contaminated data. The proposed algorithm aims to be used as the core estimator of identification methods devoted to the health monitoring of heritage buildings as well as ordinary and strategic structural systems, and it is suitable for a multitude of tasks ranging from the simple OMA to the complex online assessment of the structural response during seismic events.

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