Recent Advances in Multi-scale Nonlinear System Identification with Application to Structural Health Monitoring

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We present the basic elements of a time-domain nonlinear system identification (NSI) technique based on multiscale dynamic partitions and direct analysis of measured time series. No presumptions regarding the type, smoothness and degree of system nonlinearity are made, so the method is applicable to broad classes of applications involving time-variant/time-invariant, linear/nonlinear, and smooth/non-smooth dynamical systems. The method leads to reduced order models of simple form; *i.e.*, in the form of coupled or uncoupled oscillators with time-varying or time-invariant coefficients forced by nonhomogeneous terms representing nonlinear modal interactions. Key to our method are the slow/fast partitions of measured time series which enable the identification of the basic time scales of the evolving dynamics, and the subsequent development of slow-flow models governing the important dynamics of the system. In contrast to existing methods, our proposed methodology is especially suitable for systems with nonsmooth dynamics, leading to a partition of the smooth and nonsmooth effects in the measured time series. As such this methodology can be applied to structural health monitoring of systems with developing faults such as cracks, clearances, vibro-impacts or other abnormalities producing 'hard' nonlinearities, where it is important to detect a fault early on before it leads to uncontrollable operation or even catastrophic effects. In addition, our method is suitable for robust nondestructive monitoring and prognosis of structural components like mechanical joints where no simple and economically feasible monitoring techniques are currently available.