

Direct Identification of the State Equation in Complex Nonlinear Systems

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A crucial element in the modeling and control of adaptive (“smart”) systems, is the ability to develop high-fidelity, reduced order and reduced complexity nonlinear (i.e., not-necessarily linear) mathematical models for the physical systems of interest. Building on the basic idea behind the *Restoring Force Method* for the nonparametric identification of nonlinear systems, a general procedure is presented for the direct identification of the state equation of complex nonlinear systems. No information about the system mass is required, and only the applied excitation(s) and resulting acceleration are needed to implement the procedure. Arbitrary nonlinear phenomena spanning the range from polynomial nonlinearities to the noisy Duffing–van der Pol oscillator (involving product-type nonlinearities and multiple excitations) or hysteretic behavior such as the Bouc-Wen model can be handled without difficulty. In the case of polynomial-type nonlinearities, the approach yields virtually exact results. For other types of nonlinearities, the approach yields the optimum (in least-squares sense) representation in nonparametric form of the dominant interaction forces induced by the motion of the system. Several examples involving synthetic data corresponding to a variety of highly nonlinear phenomena are presented to demonstrate the utility as well as the range of validity of the proposed approach.

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