Repeated exponential sine sweeps for the autonomous estimation of nonlinearities and bootstrap assessment of uncertainties

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Systems and structures are generally assumed to behave linearly and in a noise-free environment. This is in practice not perfectly the case. First, nonlinear phenomena can appear and second, the presence of noise is unavoidable for all experimental measurements. Nonlinearities can be considered as a deterministic process in the sense that in the absence of noise the output signal depends only on the input signal. Noise is purely stochastic: in the absence of an input signal, the output signal is not null and cannot be predicted at any arbitrary instant. It turns out that these two issues are coupled: all the noise that is not correctly removed from the measurements could be misinterpreted as nonlinearities, and if nonlinearities are not accurately estimated, they will end up within the noise signal and information about the system under study will be lost. The underlying idea consists here in extracting the maximum of available linear and nonlinear deterministic information from measurements without misinterpreting noise.

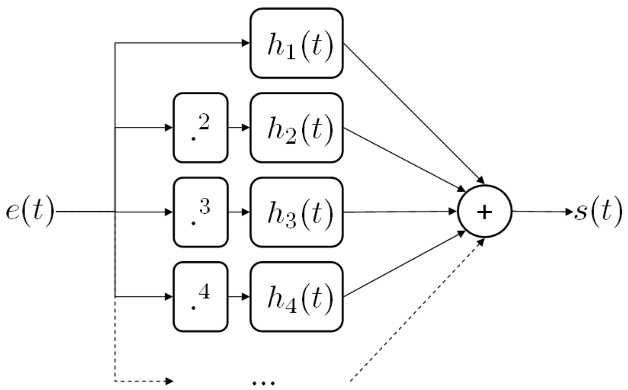

Figure 1: A cascade of Hammerstein models

The first problem addressed here is related to the estimation of nonlinear models [1]. We choose here to rely on black-box models having a given block-oriented structure. A class that is particularly interesting is the class of parallel Hammerstein models (see Fig. 1) as it is shown to possess a good degree of generality [1]. Moreover, thanks to exponential sine sweeps, nonparametric versions of such models can be very easily and rapidly estimated [2]. The second problem addressed here is related to the estimation of uncertainties in the context of nonlinear system estimation. The use of multiple exponential sine sweeps allows for a more robust and efficient estimation of nonlinear models of vibrating structures as estimation uncertainties can be simultaneously assessed using repetitions of the input signal as the input of a bootstrap procedure (see Fig. 2) [3].

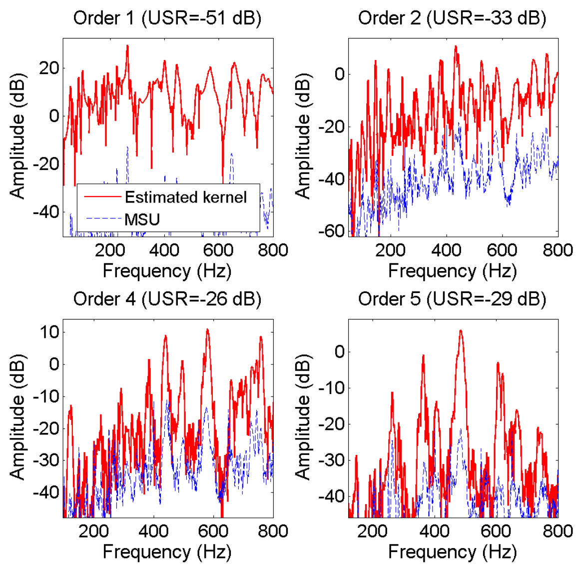

Figure 2: Illustration of the frequency gains of kernels estimated by synchronously averaging different periods of the excitation signal together with the mean square uncertainty obtained by bootstrap [3].

Our contribution to this workshop would thus be to assess the efficiency of this methodology [3]. In our opinion this method is interesting as it is in practice really easy to implement and do not rely on complex and computationally demanding signal processing or optimization steps. However this method is strongly linked with parallel Hammerstein models which cannot represent all the nonlinear systems and some limitations are expected here.

References

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