Phase-based homogeneous order separation for improving Volterra series identification

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1 Introduction and problem statement

The current work focuses on improving estimation of nonlinear systems that allows a polynomial-like input-output description; this is done by using an order separation method prior to identification. The results will be presented in the framework of Volterra series, but are applicable for polynomial block structure (Hammerstein, Wiener, ...) or even polynomial nonlinear state-space system.

For a system that admits a Volterra series representation, the output can be written

$$y(t) = \sum_{n=1}^{\infty} y_n(t) = \sum_{n=1}^{\infty} V_n\left[u\right](t),$$

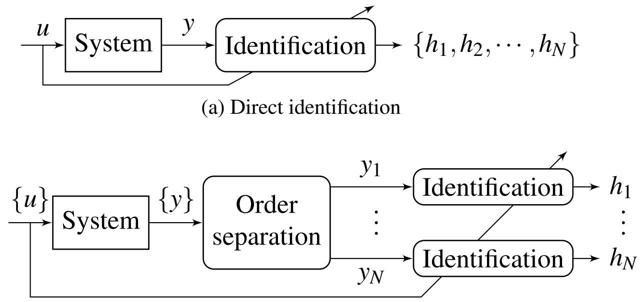
where y_n are the nonlinear homogeneous order of the system, and where each operator V_n is completely described by the Volterra kernel h_n.
Most of Volterra identification methods exploit directly the raw output signal y in order to identify a set of kernels $\{h_n\}, n = 1, \ldots, N$ (as shown in Figure 1a). Due to the amplitude differences between the y_n (overall, it decreases as n increases), this simultaneous estimation will be less reliable for higher-order kernels. In order to circumvent this difficulty, it is possible to divide the identification into 2 steps (as shown in Figure 1b):

1. first we separate the nonlinear homogeneous orders y_n, $n = 1, \ldots, N$ from a set of output signals;
2. then we identify separately the kernels h_n on each signal y_n.

This two-part approach has the benefit of being modular: any existing identification methods can be used [1–3]. But the existing order separation method relies on amplitude differences between test signals [4], which leads to several drawbacks (large range of amplitudes needed for excitation, bad conditioning). Its use is in practice limited to the first few orders.

2 Methodology and applications

This contribution presents the design of a robust order separation method relying on phase deconstruction and reconstruction between tests signals. It extends the previous results of the authors that can be found in [5].



(b) Identification on separated order

Figure 1: Identification process without (a) and with (b) prior order separation.

First a theoretical method using complex-valued signals is introduced. Then extension to real-valued signals is made, where multilinearity of the orders y_n has to be taken into account (instead of homogeneity). The proposed order separation method is evaluated and compared to the state-of-the art one on simulated versions of the Wiener-Hammerstein and Silverbox benchmark systems.

References

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