



HAL
open science

Phase-based homogeneous order separation for improving Volterra series identification

Damien Bouvier, Thomas Hélie, David Roze

► **To cite this version:**

Damien Bouvier, Thomas Hélie, David Roze. Phase-based homogeneous order separation for improving Volterra series identification. Workshop Nonlinear System Identification Benchmarks, Apr 2018, Liège, Belgium. hal-01934720

HAL Id: hal-01934720

<https://hal.science/hal-01934720v1>

Submitted on 24 Jan 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Phase-based homogeneous order separation for improving Volterra series identification

Damien Bouvier, Thomas Hélie and David Roze

Team Sound Signals and Systems : Audio/Acoustics, instruMents (S3AM),
 STMS (UMR9912), Sorbonne Université, 1, Place Igor Stravinsky, 75004, France
 damien.bouvier@ircam.fr

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

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

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 $\{h_n\}, n = 1, \dots, N$ (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 $y_n, n = 1, \dots, N$ 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].

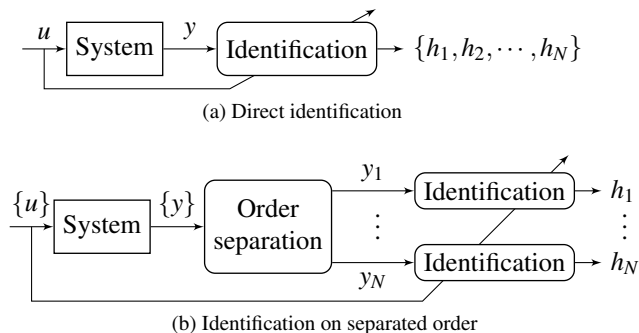


Figure 1: Identification process without (a) and with (b) prior order separation.

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

- [1] Stephen P. Boyd, Y. S. Tang, and Leon O. Chua. Measuring volterra kernels. *IEEE Trans. Circuits Syst.*, 30(8):571–577, 1983.
- [2] Delphine Bard and Göran Sandberg. Modeling of Nonlinearities in Electrodynamical Loudspeakers. In *Audio Engineering Society Convention 123*. Audio Engineering Society, 2007.
- [3] B. Zhang and S.A. Billings. Volterra series truncation and kernel estimation of nonlinear systems in the frequency domain. *Mechanical Systems and Signal Processing*, 84:39–57, 2017.
- [4] Russell H. Lambert. Vandermonde Method for Separation of Nonlinear Orders and Measurement of Linear Response. In *Audio Engineering Society Convention 141*. Audio Engineering Society, 2016.
- [5] Damien Bouvier, Thomas Hélie, and David Roze. Nonlinear Homogeneous Order Separation for Volterra Series Identification. In *Proceedings of the 20th International Conference on Digital Audio Effects (DAFx'17)*, pages 3–10, Edinburgh, UK, 2017.