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Identification of Complex Systems with the use of Interconnected Hammerstein Models

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Abstract

In the paper we consider the problem of identification of large-scale interconnected systems. Accurate models of complex nets are needed especially for optimal control in production and transportation systems. The specifics lay in the fact that individual elements cannot be disconnected and excited by arbitrary input processes for identification purposes. Moreover, structural interactions cause correlations between interaction signals. In particular, any output random disturbances can be transferred into the other inputs. It leads to cross-correlation problems, very difficult from the effective modelling point of view. First attempts made in 1980's were limited to static linear blocks, and in practice the results were rather devoted to linear dynamic systems working in steady state. In this paper we generalize the approach for components, which are both dynamic and nonlinear. All blocks are represented by two-channel Hammerstein systems (used e.g. in modelling of real heating processes). The least squares estimate is applied to identify unknown parameters of a system. The parameters of particular elements are obtained in singular value decomposition procedure. The algorithm as a whole is illustrated in simple simulation example.

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Keywords: Hammerstein system, Wiener system, system identification, least squares, instrumental variables

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1. Introduction

1.1. Identification of complex systems

The purpose of system identification is to build the model, which describes relation between the input and output processes, using the prior knowledge of the system characteristics (e.g. laws of physics) and the measurement data. Adequate models allow for system simulation, design of optimal decision and control, fault detection and forecasting of system behavior. It is often of crucial meaning from the economical point of view. Correct decisions made in the system input allow to save time, energy and money. As regards the state of the art in system identification framework, we have a lot of identification methods elaborated over the last decades (Söderström and Stoica, 1989). Starting from the traditional least squares and correlation based estimates applied to linear dynamic system identification, the ideas were generalized towards the least possible a priori restrictions imposed on the system characteristics. In particular, the nonlinear models represented by Volterra series expansions were first considered. Owing to high computational complexity they were displaced with the conception block- oriented models i.e. Hammerstein systems and Wiener systems, including serial connections of static nonlinear and linear dynamic blocks (Mzyk, 2014b and Giri and Bai, 2010). Nevertheless, the identified plants were usually considered separately, in the sense that the input process could be freely generated and the object could work independently of the other ones. In practice, the object input process depends on the outputs of the other cooperating elements. It leads to serious limitations making the identification problem more difficult. In particular, the input process as the output of other dynamics can by correlated and application of traditional procedures can be excluded. This aspect is very important and often met in production and transportation systems. It was shown in Hasiewicz (1987 and 1989), that even for the static linear blocks, identifiability of individual element in complex system depends on both the interconnection structure and the values of parameters of complementary blocks. Moreover, the random disturbances present on outputs can be transferred to the inputs by the structural feedback. In consequence, standard theory cannot be directly applied for complex system identification. The control of complex system problem was raised and analyzed in 1980s by the team of prof. W. Findeisen (1980). The whole system was splitted into smaller subproblems (Fig. 1), and the control quality indexes were optimized separately (and in parallel) under the supervising coordination layer. Similar strategy is proposed in this paper. Thanks to the knowledge of the system structure, the inputs are evaluated for individual blocks and next, the least squares are applied for its identification.

The paper is focused on the system including two (or more) mutually dependent nonlinear dynamic objects. Both the object and the dependencies are represented with the use of Hammerstein model. The proposed algorithm makes generalization of the methods proposed in Mzyk (2012, 2014a) towards nonlinear dynamic blocks. Hammerstein branches are identified by the concept presented in Bai (1998) and Mzyk (2013, 2015). The main contribution of the paper is application of least squares method for complex nonlinear dynamic systems.

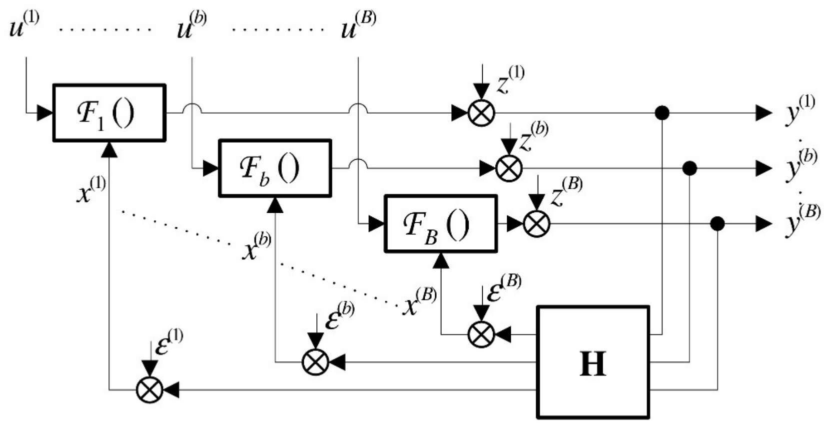

Fig. 1. Complex system.

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