Preface

The identification of nonlinear systems using the block-oriented approach has been developed since the half of 1960s. A large amount of knowledge on this subject has been accumulated through literature. However, publications are scattered over many papers and there is no book which presents the subject in a unified framework. This has created an increasing need to systemize the existing identification methods and along with a presentation of some original results have been the main incentive to write this book. In writing the book, an attempt has been made at the presentation of some new ideas concerning the model parameter adjusting with gradient-based techniques.

Two types of models, considered in this book, use neural networks and polynomials as representations of Wiener and Hammerstein systems. The focus is placed on Wiener and Hammerstein models in which the nonlinear element is represented by a polynomial or a two-layer perceptron neural network with hyperbolic tangent hidden layer nodes and linear output nodes. Pulse transfer function models are common representations of system dynamics in both neural network and polynomial Wiener and Hammerstein models.

Neural network and polynomial models reveal different properties such as the approximation accuracy, computational complexity, available parameter and structure optimization methods, etc. All these differences make them complementary in solving many practical problems. For example, it is well known that the approximation of some nonlinear functions requires polynomials of a high order and this, in turn, results in a high parameter variance error. The approximation with neural network models is an interesting alternative in such cases.

The book results mainly from my research in the area of nonlinear system identification that have been performed since 1995. Two exceptions from this rule are Chapter 1, containing the introductory notes, and Chapter 5, which reviews the well-known Hammerstein system identification methods based on polynomial models of the nonlinearity. In writing the book, an emphasis has been put on presenting various identification methods, which are applicable to both neural network and polynomial models of Wiener and Hammerstein systems, in a unified framework.

The book starts with a survey of discrete-time models of time-invariant dynamic systems. Then the multilayer perceptron neural network is introduced and a brief review of the existing methods for the identification of Wiener and Hammerstein systems is presented. Two subsequent Chapters (2 and 3) introduce neural network models of Wiener and Hammerstein systems and present different algorithms for the calculation of the gradient or the approximate gradient of the model output w.r.t. model parameters. For both Wiener and Hammerstein models, the accuracy of gradient evaluation with the truncated backpropagation through time algorithm is analyzed. The discussion also includes advantages and disadvantages of the algorithms in terms of their approximation accuracy, computational requirements, and weight updating methods. Next, in Chapter 4, we present identification methods, which use polynomial models of Wiener systems. The parameters of the linear dynamic system and the inverse nonlinearity are estimated with the least squares method, and a combined least squares and instrumental variables approach. To estimate parameters of the noninverted nonlinearity, the recursive prediction error and the pseudolinear regression methods are proposed. Then the existing identification methods based on polynomial Hammerstein models are reviewed and presented in Chapter 5. Wiener and Hammerstein models are two examples of block-oriented models which have found numerous industrial applications. The most important of them, including nonlinear system modelling, control, and fault detection and isolation, are reviewed in Chapter 6. This chapters presents also two applications of Wiener and Hammerstein models – estimation of system parameter changes, and modelling vapor pressure dynamics in a five stage sugar evaporation station.

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