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Improved method for development of parsimonious orthonormal basis filter models

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ABSTRACT

One of the major advantages of orthonormal basis filter (OBF) models is that they are parsimonious in parameters. However, this is true only if appropriate type of filter and reasonably accurate dominant poles of the system are used in developing the model. An arbitrary choice of filter type and poles may lead to non-parsimonious model. While the selection of the type of filter may be simple if the damping characteristics of the system are known, finding good estimates of the dominant pole(s) of the system is not a trivial task. Another important advantage of OBF model is the fact that time delays can be easily estimated and incorporated into the model. Currently, time delay of the system is estimated from the step response of the OBF model using the tangent method. While this method is effective in estimating the time delay of systems that can be accurately modeled by first order plus time delay (FOPTD) models, the accuracy is low for systems with second- and higher-order dynamics. In this paper, a scheme is proposed that will result in parsimonious OBF model and a better estimate of time delay starting from an arbitrary set of poles.

1. Introduction

In order to satisfy the rapidly growing environmental and safety requirements and global competitions of modern industries numerous model based technologies have been developed. Model based control, fault diagnosis, fault tolerant control and soft sensors are a few of these technologies. The model of the system is the essential component in all these technologies. In model predictive control (MPC) systems, models are used to predict the future values of the output which is used in calculating the optimal control moves. There are several linear model structures with various characteristics. Some of the most important factors in selecting model structures are the consistency of the model and the computational load in estimating the model parameters and in implementation of the models [1,2]. Another important factor affecting the quality of dynamic models is the effectiveness in handling time delays in the system.

Orthonormal basis filter (OBF) models have several advantages over the conventional linear models, like finite impulse response (FIR), autoregressive with exogenous input (ARX), etc. They are consistent in parameters for most practical open-loop systems. They require relatively a fewer number of parameters to capture the dynamics of linear systems (parsimonious in parameters) and the model parameters can be easily estimated using linear least square method [2–5]. In addition, time delays can be easily estimated and incorporated into the model [5]. Generalized orthonormal basis filter (GOBF) models have already been used in MPC and fault tolerant control systems with significant improvement in control system performance [6]. The basics of OBF models have been discussed in a number of publications [2–13].

Development of parsimonious OBF models that have acceptable accuracy is possible if appropriate type of filter and good estimates of dominant poles of the system are used in developing the model [3,7]. If the appropriate type of filter and estimates of the dominant poles of the system cannot be obtained, an arbitrary choice of filter type and pole may lead to non-parsimonious model. In our previous work [8], a scheme that improves the prediction capability of OBF models by including a noise term has been developed. The result was Box–Jenkins type structures with OBF model as the deterministic component. It was, however, observed that while the OBF model development itself appears simple, there is in fact no clear, systematic way of determining the number of parameters, the dominant poles of the system and the type of filter to be used for a given set of identification data. Patwardhan and Shah [5] suggested that the poles to be used in the GOBF model can be estimated from step response data. There are two major disadvantages in this approach. First, in cases where the system is subjected to considerable disturbances, it is too difficult to isolate the system and conduct a step test that enables a good estimate of the dominant poles of the system. The second major disadvantage is the fact that there

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