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Closed-loop identification of systems with uncertain time delays using ARX–OBF structure

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ABSTRACT

Closed-loop identification of systems with known time delays can be effectively carried out with simple model structures like Autoregressive with Exogenous Input (ARX) and Autoregressive Moving Average with Exogenous Input (ARMAX). However, when the system contains large uncertain time delay, such structures may lead to inaccurate models with significant bias if the time delay estimate used in the identification is less accurate. On the other hand, conventional orthonormal basis filter (OBF) model structures are very effective in capturing the dynamics of systems with uncertain time delays. However, they are not effective for closed-loop identification. In this paper, an ARX–OBF model structure which is obtained by modifying the ARX structure is shown to be effective in handling closed-loop identification of systems with uncertain time delays. In addition, the paper shows that this advantage of ARX–OBF models over simple ARX model is considerable in multi-step ahead predictions.

1. Introduction

Process models are at the center of the design and implementations of several modern control theories. The model of a process to be controlled is essential in optimal control, model predictive control (MPC) and other model based control approaches. In MPC, models are used to predict the future values of the output of the system which is used in calculating the optimal control moves [1–4]. A complete design of MPC includes the necessary mechanism for obtaining the best possible model, which captures the dynamics fully and allows the prediction to be calculated [1,2]. First principle models are developed using conservation principles, thermodynamic and other physical and chemical principles. Such models however are very rarely used in practice because of the prohibitively considerable effort and time required to get a reasonably accurate model for complex industrial systems. System identification is the process of developing models from experimental data. Such models are very common in industrial applications. System identification can be carried out using input–output data either from open-loop or closed-loop tests. When a system identification test is carried out in the open loop, mostly, the noise sequence is not correlated to the input sequence and models with Finite Impulse Response (FIR), Output Error (OE), Box-Jenkins (BJ) and OBF structures can be directly developed without problems of inconsistency and bias. However, when system identification test is carried out in closed loop, i.e., under a feedback controller that is not identically zero, the input sequence is correlated to the noise sequence [5–8]. In such cases, most of the structures that are effective for open-loop identification result in models that are biased and not consistent in parameters [7,8]. Regardless of this, there are several cases where conducting control relevant system identification test in closed loop is the most acceptable option. Two of the most compelling cases are when safety considerations might not allow the process to run in open-loop and when the process is open-loop unstable and a controller is required to stabilize the system. It is also shown by Gevers and Ljung [9] that for minimum variance control design the identification experiment should be performed in closed loop with the optimal minimum variance controller in the loop. In addition, in identification for control the objective is to achieve a model that is suited for robust control design and the identification test should be conducted in closed loop [10,11].

Forssell and Ljung [5] presented a very comprehensive review of closed-loop identification: the various methods and results available with some detailed mathematical analysis. Van den Hof [6] also discusses the various issues and approaches in closed-loop system identification of both parametric and non-parametric models. There are three parametric identification approaches [5–8].

- direct identification,
- indirect identification,
- joint input/output identification.

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