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Closed-loop identification with routine operating data: Effect of time delay and sampling time☆

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ABSTRACT

In industry, in order to store the reams of data that are collected from all the different flow, level, and temperature sensors, the fast-sampled data is very often downsampled before being stored in a data historian. This downsampled or even compressed data is, then, often used by process engineers to recover the appropriate process parameters. However, little has been written about the effects of the sampling on the quality of the model obtained. Therefore, in this paper, the effects of sampling time are investigated from both a theoretical and practical perspective using results that come out of the theory of closed-loop system identification with routine operating data. It is shown that if the discrete time delay in a process is sufficiently large or the sampling time is sufficiently small, then it is possible to recover the true system parameters. The most common industrial processes that fulfill this constraint are temperature control loops. These results suggest that the sampling time has an important bearing on the quality of the model estimated from routine operating data. Using both Monte Carlo simulations and an experimental set-up with a heated tank, the effect of discrete time delay on the identification of the true continuous time parameters was considered for different sampling times. It was shown that increasing the sampling time above a given threshold resulted in identifying an incorrect model. As well, the models obtained using a PID controller were less sensitive to sampling time than those obtained using a PI controller. However, the PID controller values were more sensitive to the effects of aliasing at larger sampling times.

1. Introduction

In industry, data obtained from sampling sensors every second or faster can quickly accumulate and become an issue to store. In order to lighten the storage requirements, the accumulated data is downsampled or even compressed. Different compression algorithms are used industrially. Furthermore, in the process industry, it is common to use the compressed historical routine operating data in order to determine process models. Thus, in this paper, the effect of downsampling on closed-loop system identification is considered. This data can be characterised as closed-loop, discrete, routine operating, process data that has been obtained without any external excitation other than natural disturbances. Therefore, there is need to consider the conditions under which data is usable for determining a process model.

The earliest work in discrete closed-loop identification, which includes [1,2,14], focused on theoretically determining the restrictions on the delay that guaranteed consistency of the parameter estimates in the absence of a reference signal or external excitation. A solution for an autoregressive moving average model with exogenous input (ARMAX) with at least a single sample delay was determined in [14] as a function of the sample delay. A similar, more general result was also considered in [13], where it was assumed that pole-zero cancellations were *a priori* known. In addition to the above theoretical results, various qualitative statements have been shown to apply for closed-loop identification. For example, it was shown that if the controller is of higher order than the process or with significant nonlinearities, then it is possible to identify the process successfully [8]. Furthermore, it has been shown that, if a reference signal is sufficiently persistently exciting for the open-loop process, then it is possible to identify the process from closed-loop data [8]. More recently, general quantitative conditions for identification of closed-loop process were presented in [3,4] for different models assuming that there were no closed-loop, pole-zero cancellations using two different approaches: an expectation-based and information matrix-based approaches. Recently, the conditions for identifiability that include closed-loop pole-zero cancellations were developed for the case

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