Closed-loop identification using direct approach and high order ARX/GOBF-ARX models

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A B S T R A C T

Model accuracy plays a key role in the performance of advanced, model predictive control algorithms. Model fidelity is usually affected by routine operating condition changes, which necessitate reidentification. From several theoretical and practical considerations, it is recommended that such re-identification be performed under closed-loop conditions. The direct approach for closed-loop identification, owing to its simplicity, is better suited for MPC. In order to yield unbiased and consistent parameter estimates, however, this approach requires the noise model to be sufficiently parameterized. Towards this objective, high order ARX models are the most suitable candidates from the viewpoint of ease of parameter estimation. For multivariable systems, however, the identification of high order ARX models would require longer experiments to be performed. This being undesirable from a practical viewpoint, there is a need for a parsimonious parameterization that would retain the benefits of high order ARX models. In this work, we propose to use generalized orthonormal basis filters (GOBFs) to achieve this parsimonous parameterization. Further, we propose an approach to obtain reduced order models by emphasizing important frequencies so as to suitably shape the bias. We also show that the choice of the GOBF parameterization has another important merit, viz. their ability to perform well even with minimal perturbation data or short experiment times. The efficacy of the proposed approach is demonstrated via simulations on the benchmark Shell Control Problem and a laboratory quadruple tank setup.

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1. Introduction

Nonlinear and time-varying nature of chemical processes or changes in operating region often make it necessary to update the model used in model predictive control formulations for meeting the performance requirements. If the need for re-identifying the model arises, closed loop identification is preferable due to a number of reasons. Closed loop identification, as is well known, is more aligned, relative to open loop identification, towards meeting the operating goals of the plant. Most importantly, when the model-plant mismatch (MPM) is moderately small the plant is still stabilizable using the model over a relatively wide range of perturbations that are necessary for generating sufficiently rich data. Another equally important aspect is that data generated under closed loop is more likely to contain control-relevant frequencies and so a controller based on the resulting model would be more suited to meet the performance specifications [1,2].

On the other hand, closed-loop conditions pose additional challenges for system identification. The fundamental problem is that of the correlation between the disturbances and the manipulated variables through the feedback. This correlation results in biased estimates of the model parameters when directly identifying the process dynamics from closed-loop input–output data. The awareness of these potential failings has motivated research efforts, which in turn have led to a better understanding of the properties of the existing methods when used with closed-loop data, as well as proposition of some remedies to circumvent the potential problems. Refs. [3–6] have presented comprehensive surveys on closed-loop identification.

On the basis of the assumptions on the nature of the feedback (or controller), these closed-loop identification techniques can be broadly classified into three approaches. In the first approach, known as the *direct approach*, the effect of feedback is ignored and the process dynamics are identified directly from the input and output measurements using any open-loop identification technique such as the prediction error minimization (PEM). The second approach which is called the *indirect approach* involves estimation of a closed-loop transfer function (sensitivity) followed by estimation of the open-loop transfer function using the knowledge of the controller. The third approach, which is based on the assumption that the controller is linear, consists of two steps and is known as the *joint input–output approach*. In the first step, the sensitivities of the inputs and outputs with respect to an external signal (usually the reference/setpoint signal) are estimated. The second step