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Sensitivity Compensating Control: Data-driven model based adaptive approach

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ABSTRACT

A novel Sensitivity Compensating Control (SCC) approach is proposed in a data-driven model based platform and combined with an Extended External Reset Feedback (EERF) method to handle sensitivity, input saturation, and accurate process model requirement problems associated with application of Generic Model Control (GMC). Two versions of Adaptive GMC (AGMC) are proposed using linear-in-parameters time-series models with time-varying parameters for higher relative degree systems, and are used in the formulation of SCC and EERF approaches. The steps involved in the proposed approach consist of defining a new process, control law and set point such that the determined control action drives the original process to its desired set point. The performance of the proposed control algorithms is illustrated by application to a benchmark multi-product polymerization reactor control challenge problem. The proposed approaches are applicable to chemical engineering systems exhibiting input sensitivity.

1. Introduction

Generic Model Control, GMC [1] has been one of the most widely reported nonlinear model based control approaches mainly due to its simplicity. Some of the main problems associated with application of GMC are accurate model requirement, input saturation due to physical bounds, and sensitivity between input and output variables leading to large input changes for small output change requirements. A novel sensitivity compensating nonlinear control (SCNC) approach has been proposed in a companion paper [2] to handle the sensitivity problem explicitly and an Extended External Reset Feedback (EERF) method has been incorporated into the scheme to handle the input saturation problem. The proposed approaches have been formulated using an exact model-based platform based on the assumption that an accurate process model is readily available. In this study, the SCNC and EERF approaches are proposed on a data-driven model based platform in order to address the problem of accurate process model requirement.

Inability to deal with plant model mismatch and unmeasured disturbances systematically has been one of the main difficulties associated with conventional mechanistic model based control formulations. In order to overcome this limitation, Xie et al. [3] have proposed two versions of Adaptive GMC (AGMC) based on nonlinear state estimator (Strong Tracking Filter, STF). The first one is based on simultaneous state and parameter estimation, whereas the second one estimates the input-equivalent-disturbance on-line by dumping the time-varying parameters, unmeasured disturbances and un-modeled dynamics into the input space. In another AGMC formulation, Guo et al. [4] have employed a nonlinear observer to estimate the unknown process parameters, which are incorporated into a multivariable GMC law. Jana et al. [5] have estimated the states either with the help of a reduced order model or a full model and proposed the use of Globally Linearizing Control (GLC) with predictive controllers as external linear controllers for multivariable distillation control. Wang et al. [6,7] have extended AGMC formulation to higher relative degree multivariable processes.

The above approaches have been based on the dynamic or steady state model based on first principles. The most difficult and time-consuming step in implementation of these methods is the development of a reliable first principles model for the process under consideration. Moreover, all the state variables need to be measured in order to derive an explicit control law. The second problem can be handled through observers to infer unmeasured states from measured ones. However, the first problem needs an accurate representation of the process dynamics. An approximate process model can differ from the first principles model in two ways: one in which the structure of both the models is the same, but the parameters are different (i.e. parametric mismatch) and the other in which the structure of the approximate model differs from the first principles model (i.e. structural mismatch). Lundberg and Bezanson [8] have shown that GMC takes care of parametric mismatch for under-damped closed-loop specification, but cannot handle over-damped closed-loop specification, and therefore proposed a Robust GMC (RGMC) approach by incorporating derivative feedback, which was able to handle parametric mismatch for an over-damped closed-loop specification. But neither GMC nor RGMC was able to handle structural mismatch. However, in prac-

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