Multivariable Constrained Adaptive Predictive Control based on Closed-loop Subspace Identification

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***Abstract*—**In order to deal with nonlinear, time-varying, and multivariable constrained characteristics in closed-loop industrial processes, a multivariable constrained adaptive predictive control (CAPC) method based on closed-loop subspace identification is proposed. The state-space model is obtained through the closed-loop subspace identification algorithm, which is regarded as the system model. The algorithm is implemented online to update the R matrix with a receding window. By comparing the prediction errors before and after updating, it considers whether or not to update the system model. The model is then used to design the model predictive controller, which involves the solution of a quadratic program solving multivariable constraints. This paper presents a comparison between the performance of the proposed control method when applied to a 2-CSTR system, and that of an open-loop subspace CAPC method. The superiority of the proposed method is illustrated by the simulation results.

***Keywords*—**Closed-loop Subspace Identification, Multivariable constraint, Adaptive Predictive Control, 2-CSTR

I. Introduction

Model predictive control (MPC) has been an attractive subject in the control theory field for decades. It has become more established in the industry as the one of the choices for control architecture, especially with the improvement of computational capabilities of processors [1-4]. The traditional industrial predictive control is based on the input-output model, and includes both parametric and nonparametric models. In order to improve the control performance, a state space model should be adopted so the modern filter theory and the design method of controllers developed in recent years can play a role [5-7]. However, MPC was unable to obtain the accurate state-space model among the complex industrial targets due to the limitation of the identified method. The subspace identification method has changed this situation substantially; the control workers may be completely relieved from the tedious modeling via this mechanism. The accurate state-space model can be obtained when there is enough process input and output data [8-9].

In practice, it is often necessary to perform identification experiments on systems operating in a closed loop. This is especially true when open-loop experiments are not allowed due to reasons of safety (unstable processes) or production (undesirable open-loop behavior). System identification from closed-loop data is thus a relevant topic [10]. The identification of the subspace matrices from closed-loop data has also received attention from several researchers [11]. It has been found that the regular open-loop subspace identification algorithm yields a biased estimate when applied to closed-loop data [12]. This paper expands upon some recent ideas for developing subspace methods that can perform well on data collected in a closed-loop condition. Here, a method that aims at minimizing the prediction errors in several approximate steps is proposed. The steps involve using constrained least squares estimation on models with different degrees of structure, such as the block-Toeplitz model, and reduced rank matrices.

The batch form is employed for data processing in a basic subspace identification algorithm. The acquired input-output data is processed as a whole. It is adverse to the online implementation and adaptive identified application. Due to the time-varying nature of industrial processes, online model assessment is necessary for determining whether model re-identification is needed [13]. At present, there are two ways to conduct online adaptive subspace identification; one is the recursive identification method [14], and the other is the receding window method [15]. The primary obstacle to the implementation of adaptive subspace identification is developing online QR and SVD decomposition algorithms. A QR decomposition procedure is proposed by simultaneously applying data updating and downdating, and outperformed traditional algorithms in terms of computational efficiency. Multivariable constraints arise due to physical limitations, quality specifications, safety concerns, and limiting the wear of the equipment [16]. The prediction capability of MPC is useful in anticipating constraint violations and correcting them in an

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