Polymer Quality Control Using Subspace-based Model Predictive Control with BLUE Filter

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ABSTRACT

In this study, we consider a multi-input multi-output styrene polymerization reactor system for which the monomer conversion and the weight average molecular weight are controlled by manipulating the jacket inlet temperature and the feed flow rate. The reactor system is identified by using a linear subspace identification method and then the output feedback model predictive controller is constructed on the basis of the identified model. Here we use the Best Linear Unbiased Estimation (BLUE) filter as a stochastic estimator instead of the Kalman filter. The BLUE filter observes the state successfully without any a priori information of initial states. In contrast to the Kalman filter, the BLUE filter eliminates the offset by observing the state of the augmented system regardless of a priori information of the initial state for an integral white noise augmented system. A BLUE filter has a finite impulse response (FIR) structure which utilizes finite measurements and inputs on the most recent time interval [*i-N*, *i*] in order to avoid long processing times.

1. INTRODUCTION

In case of using system identification methods to get system matrices, an output feedback controller is used to control the system because full states are usually not available. In order to realize an output feedback controller, an observer must be implemented in the control system. In many engineering applications, we find it necessary to estimate a single or multiple-dimensional state. The problem of signal estimation deals with recovering some desired variables of a dynamic system from available information with the aid of various observers. Especially, among these observers, a stochastic observer is useful to construct a controller having integral action easily by augmenting integral white noise term in an identified system model.

When linear identification method is adapted to the nonlinear system, there exists model mismatch inherently between nonlinear plant and the identified linear model. Hence, many researchers have suggested various methods compensating for the model uncertainty, one of which is the addition of integral action to the controller in state space model realization. By adding output disturbance model to the basic structure, one can effectively consider the effect of disturbances on future outputs.

For the linear disturbance models, "type1" and "type2" models which were widely used in the linear model predictive control design (for example, Morari and Lee. 1991) are augmented to the basic state space model. In the control input calculation step, the elimination of errors that result from model mismatch is considered to be the same problem as the elimination of those from disturbances on output. In other words, one can capture any constant bias between the plant and the identified model in the same way that the effect of output disturbance is diminished. Therefore, if the combined effects of the external disturbance and the plant-model mismatch reach a constant value, the type 1 assumption along with a controller with integral action yields an offset-free performance.

Although the Kalman filter is a very popular and powerful stochastic estimator in industry, *a priori* information, *i.e.*, the mean and covariance of initial states, is often unknown since it may not be measurable. In such a case, the Kalman filter is neither unbiased nor the best. So, in order to realize output feedback controller, we use Best Linear Unbiased Estimation (BLUE) filter. A BLUE filter has a finite impulse response (FIR) structure which utilizes finite measurements and inputs on the most recent time interval [*k-N*, *k*] in order to avoid long processing times. At first a BLUE FIR filter was proposed using a maximum likelihood criterion for restricted state space signal models without system noises and inputs. There seems to be no BLUE FIR filter for general state space signal models with system noises and inputs, which is independent of the initial state. A BLUE FIR filter was obtained by using a least mean square criterion for general state space signal models with system noises and inputs.

In this study, we consider a multi-input multi-output styrene polymerization reactor system for which the monomer conversion and the weight average molecular weight are controlled by manipulating the jacket inlet temperature and the feed flow rate. The system is identified using a linear subspace identification method, and then the output feedback model predictive controller with the BLUE FIR filter is constructed on the basis of the identified model. This controller also includes the integral action to remove the steady-state offset, which may be present when a linear model based controller is used to a nonlinear system.

2. IDENTIFICATION AND CONTROLLER IMPLEMENTATION

Identification

Subspace identification algorithms always consist of three main steps. Using block Hankel matrix that consists of past input/output data, we determine system order and system matrices through three steps. At first, we calculate the projection with an LQ-decomposition and determine L_w as follows:

$$O_i \overset{LQ}{=} Y_f / _{U_f} W_p = L_w W_p \qquad (1)$$

And then we calculate the following weighted SV-decomposition and determine an estimate of the order n of the system by inspecting the number of dominant singular values:

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