Identification of process and measurement noise covariance for state and parameter estimation using extended Kalman filter

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1. Introduction

To operate a chemical process profitably, in a competitive economic environment, it becomes necessary to monitor and tightly control quality variables associated with the process. However, critical quality variables such as product concentrations in reactor/distillation column outlet streams, molecular weight distribution of a polymer melt or biomass concentration in a fermenter, are difficult to measure on-line. Even when these variables are measured through lab assays, such measurements are infrequent and typically available at irregular intervals. Moreover, even when online measurements of quality variables is feasible, it can prove to be a prohibitively costly option. In such a scenario, dynamic model based estimation of unmeasured states, or a soft sensor, is an attractive alternative for process monitoring and control. With the availability of high speed computers at relatively low costs, process monitoring and advanced multivariable control, which is based on on-line use of mechanistic models, are becoming feasible options in recent years. Since a mechanistic model is representative of the physical states of the plant, it can be used to deduce information of trajectories of internal unmeasured (or irregularly measured) states at regular and faster rate.

However, even when a reliable mechanistic model for the system under consideration is available, using it for online monitoring and control is not an easy task. Process plants are continuously affected by unmeasured disturbances of different kind and the measurements are corrupted with noise. Thus, it becomes necessary to develop state estimators that systematically fuse noisy measurements with mechanistic models to generate state estimates. The state observers can be developed either through deterministic approaches [1] or through Bayesian approaches [2]. Bayesian approaches provide a systematic approach to handle the unknown inputs affecting the states and the measurement noise. To generate reliable estimates of the unmeasured or infrequently measured states it is important to develop a reasonably accurate characterisation of these unmeasurable signals. This is a critical aspect in the development of Bayesian state estimators. An incorrect choice of noise characteristics leads to deterioration in the performance of the state estimator and, in the worst case, the estimator may diverge [3].

A commonly used assumption in the development of Bayesian state estimation is that the state and measurement disturbances...