Enhanced Robust Filtering for Linear Systems

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Abstract

In this paper, the ε-contamination observation model for time-series is presented. The least favorable contaminating density at each stage is obtained. For linear systems, the optimal robust estimator and the associated conditional covariance are presented recursively. From this robust filtering, the efficiency can be increased when more data is available. Hence, we propose the enhanced robust filtering for linear systems using future observation data to estimate the present state. We also numerically evaluate the performance of this filter comparing the performance of the Kalman filter and the performance of the optimal robust filter.

From the numerical example, estimates given by three different filters have identical estimates in the absence of data outliers. But estimates given by the enhanced robust filter provide the best estimates in the presence of consecutive data outliers.

Keywords: *Robust Kalman filtering, recursive filtering, outliers, ε-contamination model for time-series, least favorable contaminating density, linear systems*

Introduction

In the discrete-time linear systems with Gaussian random processes, Kalman filter provides a recursive solution to estimate the state of the system from past and present measurements that contain random errors (Kalman 1960). The Kalman filter has been used in control systems such as in tracking and navigation of all sorts of vehicles, and in communication systems such as in estimating the position and velocity of a satellite from radar data (Maybeck 1979; Brown 1983; Lewis 1986). This optimal estimator is linear in measurement. However, the presence of data outliers occurs in practice, the Kalman filter then may obtain inaccurate estimates.

Considering the presence of data outliers in systems, Charoenkhunwiwat (1997) presented the ε-contamination observation model and obtained the optimal robust filtering

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solution. The least favorable contaminating density at each stage was presented. The optimal robust estimator and its associated conditional covariance were expressed in recursive form for linear systems. But this robust filter may not obtain good estimates when consecutive data outliers occur.

To improve the performance of the robust filter in the presence of consecutive data outliers, we apply the smoothing technique to this filter by using future observation data. In this paper, we propose enhanced robust filtering for linear systems, and numerically evaluate the performance of this filter compared to the performance of the Kalman filter and the performance of the optimal robust filter. We consider five cases: (i) no outlier; (ii) only one outlier; (iii) two consecutive outliers; (iv) two non-consecutive outliers; and (v) three consecutive outliers.

Linear Stochastic Systems