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One approach for the detection and estimation of a jump in discrete time LTI systems

Ichiro Jikuya and Michel Verhaegen
SCE Division, Department of Applied Physics
University of Twente
P.O. Box 217, 7500 AE Enschede, The Netherlands
Email: I.Jikuya@tn.utwente.nl

1 Abstract

A deadbeat observer based generalized likelihood ratio (GLR) test is proposed for the detection and estimation of a jump in discrete time linear time invariant (LTI) systems. The proposed approach overcomes the difficulty in the choice of the window size for the online detection procedure. The marginalized GLR test is also discussed as the offline procedure to overcome the difficulty in the choice of the threshold.

2 Problem Formulation

The problem is to detect and estimate the jump ν and the jump time t_0 from the given sequence of observations $\{y(t)\}$ of the discrete time LTI system

$$\begin{aligned} x(t+1) &= Ax(t) + Gw(t) + \delta_{t_0,t}\,\nu \\ y(t) &= Cx(t) + v(t) \end{aligned}$$

where $x(t)$ is the state, $y(t)$ is the observation, and $\{w(t)\}$ and $\{v(t)\}$ are independent, zero mean, Gaussian sequences with variance $\mathbf{E}[w(t)w(t)^T] = W > 0$ and $\mathbf{E}[v(t)v(t)^T] = V > 0$. The term $\delta_{t_0,t}\,\nu$ represents a jump in the state. Here t_0 is an unknown positive integer, which assumes a value if a jump occurs and takes the value $+\infty$ if there is no jump. Also $\delta_{i,j}$ is the Kronecker delta and ν is the unknown size of the jump (see [2, 8, 4, 3] for surveys).

One of the most powerful methods for the jump detection is the GLR test proposed in [7]. The key points of the GLR test are summarized as follows. Based on the state estimation of the Kalman filter, the residual can be computed at each time instant. It does not depend on the initial state and becomes independent Gaussian sequence with/without the jump. If no jump has occurred, the mean value of the residual is 0. Once a jump occurs, the mean value of the residual is linearly dependent on the jump at each time instant. This linear dependence of the mean value together with the variance of the residual can be computed utilizing the Kalman filter gain. Since the log likelihood ratio (LLR) becomes a function of the unknown jump and the unknown jump time, they can be estimated by maximizing the LLR over a fixed interval. The choices of the window size and that of the threshold have been recognized as key problems.

3 Solution

This paper proposes a deadbeat observer based GLR test to detect and estimate the unknown jump in discrete time LTI systems, *i.e.* we apply the deadbeat observer to generate the residual as a substitute for the Kalman filter [7] and estimate the unknown jump and the unknown jump time. Compared with the Kalman filter based approach, it can be shown that we can follow the same procedure of the GLR test, and furthermore the small window size at most the McMillan degree of the LTI system is enough for the detection and estimation. Assuming the noninformative prior information for the size of the noise variance, the marginalized GLR test is discussed as an offline procedure to overcome the difficulty in the choice of the threshold (cf. [5, 6]).

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