Design of Fault Diagnosis System for the Parameter-Depended Control System

Jing Zhou

School of Mathematics & Computer Science, JiangHan University, 430056, Wuhan, China
zhou_8132@sina.com

Abstract. A robust parameter-depended reduced order(RPRO) fault detection filter(FDF) is designed. Contrary to the parameter-depended uncertainty system, the order of the linear matrix inequalities is reduced, then the RPRO fault detection and fault isolated filters are constructed. Then a RPRO fault isolation filter is designed for occurrence of both actuator fault and sensor fault in the aerocraft’s closed-loop control system, and fault diagnosis system is structured based on the fault isolation filters. Through the output of the fault diagnosis system, we can alarm the fault timely and the advantages of this approach are highlighted.

Keywords: fault detection and isolation, RPRO, parameter-depended system, bias fault, feature points.

1 Introduction

Due to the control system becomes more and more complicate, the system’s reliability and security desires more attention. Especially to the aerocraft’s control system, the fault’s occurrence will lead to inestimable loss. How to detect and isolate the fault effectively online, hence improve the reliability and security of the aerocraft’s control system is a very meaningful and valuable research topics.

A very interesting application of $H_{\infty}$ estimation algorithms to aircraft inflight ice detection was given in literature [1]. An approach in which the Luenenberger observer gains from a bank of dedicated Kalman filters are optimized for fault detection using $H_{\infty}$ optimization was proposed[2]. An application of the approach to a simplified longitudinal flight control system (i.e. short-period dynamics and LTI) with noise and disturbances resulting from Butterworth filters and considering system parameter fluctuations was given. And the $H_{\infty}$-FDI Ricatti-based approach is used to design fault detection filters for an inverted pendulum. They use parametric linear fractional transformations (LFT) to represent uncertainty and then estimate the parameter uncertainty in order to declare the fault. Unfortunately the application was not fully carried out in this case (i.e. no simulations)[3].
2 Parameter-Depended Reduced Order Fault Detection Filter Design

RPRO fault detection filter. An aerocraft’s closed-loop system with the actuator fault or sensor fault is considered. The system shown as Eq. 1 is a LTI system which is constructed at several feature points, with the parameter-depended uncertainties. where \( x(t) \in \mathbb{R}^n \) means system state, \( y(t) \in \mathbb{R}^n \) describes measurement output, \( f(t) \in \mathbb{R}^n \) describes fault function, \( d(t) \in \mathbb{R}^n \) means bounded interference, \( u(t) \in \mathbb{R}^n \) means control input signal \( B_f f(t) \) describes actuator fault and \( D_f f(t) \) means sensor fault.

\[
P: \begin{cases}
\dot{x}(t) = A(\alpha)x(t) + B_u(\alpha)u(t) + B_d(\alpha)d(t) + B_f(\alpha)f(t) \\
y(t) = C(\alpha)x(t) + D_u(\alpha)u(t) + D_d(\alpha)d(t) + D_f(\alpha)f(t)
\end{cases}
\]

(1)

For the purpose of residual generation, the so-called fault detection filter in the Eq. 2 is used, and system residual \( r(t) \) is defined as \( r(t) \equiv z(t) - y(t) \).

\[
\begin{align*}
\dot{x}_F &= A_F x_F + B_F y \\
z &= C_F x_F + D_F y
\end{align*}
\]

(2)

Then adhibiting a standard error model \( r'(s) = W_f(s)f(s) \) and the residual error is defined as \( \tilde{r} = r' - r = W_f r \). Thus, the block diagram for the residual error \( \tilde{r} \) with shaping filter \( W \) and FD filter \( F \) is shown in Fig.1. The two shaping filter \( W_d \) and \( W_F \) are used to regulate the system error which can refer to literature [4].

\[\text{Fig. 1. The block diagram for the FD structure}\]

Including the weighting functions \( W_d \) and \( W_F \) into the model (Eq. 1) leads to the standard linear-fractional form, then including the filter (Eq. 2) and using some linear fractional algebra, it can be verified that the losed-loop model \( R = (\tilde{P} \times F) \) admits the state space equation described as literature[4].