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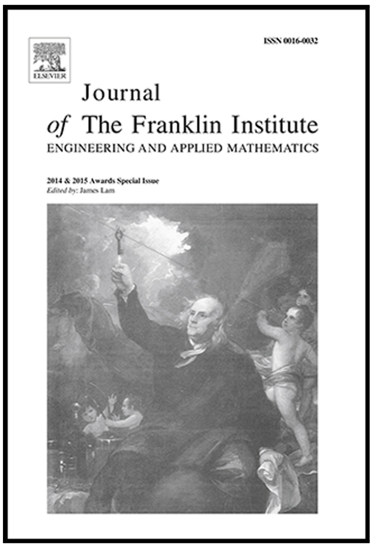

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Optimal Residual Generation for Fault Detection in Linear Discrete Time-varying Systems with Uncertain Observations

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Abstract

This work deals with the problem of optimal residual generation for fault detection (FD) in linear discrete time-varying (LDTV) systems subject to uncertain observations. By introducing a generalized fault detection filter (FDF) with four parameter matrices as the residual generator, a novel FDF design scheme is formulated as two bi-objective optimization problems such that the sensitivity of residual to fault is enhanced and the robustness of residual to unknown input is simultaneously strengthened. A generalized operator based optimization approach is proposed to deduce solutions to the corresponding optimization problems in operator forms, where the related H_∞/H_∞ or H_-/H_∞ FD performance index is maximized. With the aid of the addressed methods, the connections among the derived solutions are explicitly announced. The parameter matrices of the FDF are analytically derived via solving simple matrix equations recursively. It is revealed that our proposed results establish an operator-based framework of optimal residual generation for some kinds of linear discrete-time systems. Illustrative examples are given to show the applicability and effectiveness of the proposed methods.

Key words: fault detection, time-varying system, uncertain observation, residual, optimization

1 Introduction

To satisfy the increasing demands on safety and reliability for complex systems, much efforts have been dedicated to the fault detection (FD) realm by using observer based residual generator design approach, where this residual generator is often called fault detection filter (FDF). To handle model uncertainties and exogenous disturbances, fruitful results have been reported on the robust FDF design schemes in the past two decades, see [1–11] and references therein. The main idea behind these approaches is to employ useful optimization tools such that the sensitivity of residual to fault is enhanced, while the effects of unknown perturbations to residual is reduced. Roughly speaking, there are three main techniques to achieve robust FDF design. The first one is the well-known H_∞-like filtering scheme which minimizes the error between the residual and the fault signal within a prescribed disturbance attenuation level [2,12]. The second one is the so-called H_∞/H_∞ or H_-/H_∞ FDF design approach, which maximizes the ratio of sensitivity/robustness for FD [13–15]. For systems with additive random disturbances, the Kalman filter-like robust estimator design scheme serves as the third one to obtain useful state or fault information in the sense of minimizing the variance of the estimation error [16,17].

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