Available online at www.sciencedirect.com
ScienceDirect
Journal of the Franklin Institute 348 (2011) 179–200
Journal of The Franklin Institute
www.elsevier.com/locate/jfranklin

A delay-derivative-dependent approach to robust $H\infty$ filter design for uncertain systems with time-varying distributed delays ☆

Jiyao An[a,b], Guilin Wen[a,*], Nianfei Gan[a], Renfa Li[b]

[a] *State Key Laboratory of Advanced Design and Manufacture for Vehicle Body, the Key Laboratory of Advanced Design and Simulation Techniques for Special Equipment, Ministry of Education, Hunan University, Changsha 410082, PR China*

[b] *School of Computer and Communication, Institute of Embedded Systems and Network, Hunan University, Changsha 410082, PR China*

Received 4 March 2010; received in revised form 2 November 2010; accepted 12 November 2010
Available online 25 November 2010

Abstract

This paper focuses on the problem of robust $H\infty$ filter design for uncertain systems with time-varying state and distributed delays. System uncertainties are considered as norm-bounded time-varying parametric uncertainties. The delays are assumed to be time-varying delays being differentiable uniformly bounded with delay-derivative bounded by a constant, which may be greater than one. A new delay-derivative-dependent approach of filter design for the systems is proposed. A novel Lyapunov–Krasovskii functional (LKF) is employed, and a tighter upper bound of its derivative is obtained by employing an inequality and using free-weighting matrices technique, then the proposed result has advantages over some existing results, in that it has less conservatism and it enlarges the application scope. An improved sufficient condition for the existence of such

☆ This work was supported in part by the Cultivation Fund of the Key Scientific and Technical Innovation Project, Ministry of Education of China (No. 708067), the Special Scientific Research Fund for Doctor Subjects of Universities (No. 200805320022), and in part by the Program for Changjiang Scholars and Innovative Research Team in University (No. 531105050037).

* Corresponding author. Tel.: +86 731 8882 1482.
E-mail address: wenguilin@yahoo.com.cn (G. Wen).

doi:10.1016/j.jfranklin.2010.11.001

a filter is established in terms of linear matrix inequality (LMI). Finally, illustrative examples are given to show the effectiveness and reduced conservatism of the proposed method.

1. Introduction

The $H\infty$ filtering problem is to design an estimator to estimate the unknown state combination via output measurement, which guarantees that the L_2-induced gain from the external disturbance to the estimation error is less than a prescribed level [1–12]. The $H\infty$ filtering problem has been extensively studied over the past few decades and its applications in a variety of areas such as signal processing, signal estimation, pattern recognition and many practical control systems have been discussed. Considerable efforts have been devoted to analyzing the $H\infty$ filtering criterion without a time-varying delay [4–6]. However, time delays are frequently encountered in many dynamic systems such as chemical or process control systems and networked control systems [13], and thus recently considerable researchers have been attracted to study for various system with time-varying delays, for examples, switched systems [11,12], Markovian jump systems [14,15], singular systems [16], neutral systems [17], stochastic systems [18], nonlinear or linear systems [3,8–10,17,19–28], and uncertain case of the above systems, etc. The stability criterion for the existence of a suitable filter or controller can be classified into delay-independent [8,19] and delay-dependent [4,9–18,20–29]. The delay-independent approach has been generally considered to be more conservative than the delay-dependent one, especially in situations where delays are small, and then much attention has been paid to the delay-dependent type.

System with distributed delays will arise when the number of summands in a system equation is increased and the differences between neighboring argument values are decreased. It is often applied to the modeling of feeding system and combustion chambers in a liquid monopropellant rocket motor with pressure feeding [5]. The existence of distributed delays in a time-varying delay system may make the problem of filter design more complicated and difficult to be solved by traditional method. For instance, Zhao et al. [15] investigated the $H\infty$ guaranteed cost control problem for mode-dependent time-delay jump systems with norm-bounded uncertain parameters with both distributed delays and input delays. Xu and Chen [5,6] concerned the $H\infty$ filter design for uncertain systems with distributed delays when the delays have been assumed to be bounded by a constant. Wu et al. [9], Yu [26] and Tang [27] dealt with the same problem at the time-varying delay case. However, there have been the restrictions that the time-derivative of time-varying state delay or distributed delay must be less than one, which limits the application scope of the existing results. On the other hand, when estimating the upper bound of the derivative of LKF, some useful terms are ignored. For example, the derivative of $\int_{-h}^{0}\int_{t+\theta}^{t}\dot{x}^T(s)Z\dot{x}(s)\,ds\,d\theta$ is often estimated as $h\dot{x}^T(t)Z\dot{x}(t)-\int_{t-d(t)}^{t}\dot{x}^T(s)Z\dot{x}(s)ds$ in [4,22,30,31] and the term $-\int_{t-h}^{t-d(t)}\dot{x}^T(s)Z\dot{x}(s)ds$ is ignored, In [22], $-\int_{t-h}^{t}\dot{x}^T(s)R\dot{x}(s)ds$ was magnified $-\int_{t-\tau(t)}^{t}\dot{x}^T(s)R\dot{x}(s)ds$. Therefore, there is room for further investigation to reduce the conservatism of the filter design. This motivates the present research to develop a new method for robust $H\infty$ filter design problem with less conservatism and to enlarge the application scope for the upper bound of time-derivative of time-varying delays.