Signal Processing 94 (2014) 23–32

Contents lists available at ScienceDirect

Signal Processing

journal homepage: www.elsevier.com/locate/sigpro

Reliable H_∞ filtering for neutral systems with mixed delays and multiplicative noises ☆

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ARTICLE INFO

Article history:
Received 28 January 2013
Received in revised form
2 April 2013
Accepted 3 June 2013
Available online 11 June 2013

Keywords:
Reliable H_∞ filtering
Neutral system
Mixed delay
Multiplicative noise

ABSTRACT

This paper investigates the reliable H_∞ filtering problem for a class of neutral systems with mixed delays and multiplicative noises. The mixed delays comprise both discrete and distributed delays. And the multiplicative disturbances are in the form of a scalar Gaussian white noise with unit variance. Furthermore, the failures of sensors are quantified by a variable varying in a given interval. In the presence of mixed delays and multiplicative noises, sufficient conditions for the existence of a reliable H_∞ filter are derived, such that the filtering error dynamics is asymptotically mean-square stable and also achieve a guaranteed H_∞ performance level. Then a linear matrix inequality (LMI) approach for designing such a reliable H_∞ filter is presented. Finally, a numerical example is provided to illustrate the effectiveness of the developed theoretical results.

1. Introduction

Filtering problem has long been an important research topic for its theoretical and practical significance in signal processing, communication and control systems. The filtering problem can be briefly described as the design of an estimator from the measured output to estimate the state of the given system. In the last decade, filtering problems for various systems have attracted considerable research interests and many important results have been reported in the literature [1–4]. Among these results, the H_∞ filter minimizes the H_∞ norm of the transfer function between the noise and the estimation error. Thus, the H_∞ filter is always used when the energy of the system noise is bounded and the statistical properties of the noise are unknown. Therefore, H_∞ filtering approach has gained amount of research attention [5–12].

Recently, the control and filtering problems for systems with multiplicative noises have received much attention since many plants may be modeled by systems with multiplicative noises, and some characteristics of nonlinear system can be approximated by models with multiplicative noises rather than by linearized models [13], and the H_∞ output-feedback control as well as passive control of discrete-time systems with state-multiplicative noise has been investigated in [14,15]. Costa and Benites have studied the linear minimum mean square filter for discrete-time linear systems with Markov jumps

☆ The work is supported by the Natural Science Foundation of China under Grants 60974021 and 61125303, the 973 Program of China under Grant 2011CB710606, the Fund for Distinguished Young Scholars of Hubei Province under Grant 2010CDA081, the Specialized Research Fund for the Doctoral Program of Higher Education of China under Grant 20100142110021, National Priority Research Project NPRP 4-451-2-168, funded by Qatar National Research Fund.

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http://dx.doi.org/10.1016/j.sigpro.2013.06.002

and multiplicative noises in [16]. Furthermore, Liu et al. have considered the robust reliable control for discrete-time-delay systems with multiplicative noises. Therefore it is necessary to investigate H_∞ filtering for the systems with multiplicative noises.

On the other hand, it is inevitable that there exist time delays in dynamic systems due to measurement, transmission and transport lags, computational delays or unexpected inertia of system components, which have been known as main sources to degrade the performance of the control system [6]. In the last decade, significant progress has been made on the analysis and synthesis issues for systems with various types of delays [17–21]. As occurring so often in reality, discrete delays and distributed delays have been widely recognized. With the increasing application of digital control systems, it is meaningful to investigate the issue of how discrete and distributed delays influence the dynamical behavior of a discrete-time system. And Wang et al. have done some pioneering work about this field [19–21].

Neutral system as a special class of time delay systems appears in many dynamic systems, a number of robust stability condition have been developed for this type of systems in the last decade. Recently, extensive attention has been paid on the problem of H_∞ filtering problem for neutral systems [22,23]. Nevertheless, it can realized that, up to now, few attempts have been made towards solving the subject of the H_∞ filtering of neutral systems with mixed delays and multiplicative noises.

In practical applications, the measurement output of a dynamic system contains incomplete observations because of temporal sensor failures. The occurrence of such a phenomenon may affect the system performance, therefore, the reliable filtering problem in the presence of possible sensor failures has attracted great attention. In the past few years, a lot of research results about the reliable control and filtering problem have been reported [24,25,27]. And some novel ideas have been proposed for the design of filters for application systems [28–31], this will provide a new way for the future study of this problem. However, to the best of the author's knowledge, the research on reliable H_∞ filtering for neutral systems with mixed delays and multiplicative noises is still an open problem that deserves further investigation.

Motivated by the above discussion, in this paper, we investigate the reliable H_∞ filtering problem for a class of neutral systems with mixed delays and multiplicative noises. It is worth pointing out that the proposed filtering problem is non-trivial because of the difficulties of (i) a new Lyapunov–Krasovskii functional is introduced to account for discrete and distributed delays; (ii) the neutral elements and multiplicative noises have been considered in the design of reliable H_∞ filter; (iii) an LMI approach is developed to solve the reliable H_∞ filtering problem, where both mean-square stability and H_∞ constraints are simultaneously guaranteed.

Notation: The notation used through the paper is fairly standard. $\mathbb{N}$ is the set of natural numbers and $\mathbb{N}^+$ stands for the set of nonnegative integers; $\mathbb{R}^n$ and $\mathbb{R}^{n\times m}$ denote, respectively, the n dimensional Euclidean space and the set of all $n\times m$ real matrices. I_n is the n-dimensional identity matrix. The notation $P>0(\geq 0)$ means that P is positive definite (semi-definite). In symmetric block matrices or complex matrix expressions, we use an asterisk ($*$) to represent a term that is induced by symmetry and diag$\{\cdots\}$ stands for a block-diagonal matrix. Matrices, if their dimensions are not explicitly stated, are assumed to be compatible for algebraic operations. Let $(\Omega,\mathcal{F},\mathcal{P})$ be a complete probability space with a filtration $\{\mathcal{F}_t\}_{t\geq 0}$ containing all $\mathcal{P}$-null sets and being right continuous. $\mathbb{E}\{x\}$ stands for the expectation of stochastic variable x. $L_2[0,+\infty)$ is the space of square integrable vectors. The notation $\|\cdot\|$ stands for the usual $L_2[0,+\infty)$ norm while $|\cdot|$ refers to the Euclidean vector norm.

2. Problem formulation

Consider the following neutral system with mixed delays and multiplicative noises:

$$\begin{cases} \dot{x}(t)-C\dot{x}(t-\tau_1)=Ax(t)+A_v v(t)x(t)+A_d x(t-\tau_2)+A_i\int_{t-\tau_3}^{t}x(s)\,ds+B\omega(t), \\ y(t)=D_1x(t)+D_2\omega(t), \\ z(t)=Ex(t), \\ x(s)=\varphi(s), s\in[-\tau,0] \end{cases} \tag{1}$$

for $\tau=\max\{\tau_1,\tau_2,\tau_3\}$, $\varphi(t)$ is the initial state of the system; $x(t)\in\mathbb{R}^n$ is the state vector; $y(t)\in\mathbb{R}^r$ is the signal to be estimated; $z(t)\in\mathbb{R}^r$ is the output; $\omega(t)\in\mathbb{R}^q$ is the disturbance input, which belongs to $L_2[0,\infty)$; and $A,A_v,A_d,A_i,B,C,D_1,D_2,E$ are known real constant matrices with appropriate dimensions; $v(t)$ is a scalar Wiener process (Brownian Motion) defined on a complete probability space $(\Omega,\mathcal{F},\mathcal{P})$ with

$$\mathbb{E}[v(t)]=0,\quad \mathbb{E}[v^2(t)]=1. \tag{2}$$

Remark 1. Mixed delays are arousing increasing interest and have been intensively studied. However, almost all of the existing literature is concerned with either the discrete-delay systems [2,7,8,17,19,26] or the distributed-delay systems [21]. To the best of our knowledge, researches on neutral systems with mixed delays are scarce, especially for the H_∞ filtering problem. In this paper, both discrete delay $x(t-\tau_2)$ and distributed delay $\int_{t-\tau_3}^{t}x(s)\,ds$ have been considered simultaneously for the problem of reliable H_∞ filtering of neutral systems.